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C. Schiefferly, J. Marlow

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Aluminum honeycomb material was selected for the energy absorption material. It was selected for the following reasons; lightweight, excellent energy absorption, unaffected by moisture and resistance to corrosion.

Two sizes of TMA's were developed, one that could be mounted on a medium duty truck and one designed to be mounted on a three quarter or one-ton pickup.

Truck TMA

Nine crash tests were conducted. Cars weighing 2,100 lbs. and 4,400 lbs. impacted the TMA's at 45 mph. All TMA's tested were 7 ft. 0 in. long by 7 ft. 8 in. wide by 2 ft. 0 in. high with various volumes of honeycomb aluminum. The TMA's were mounted on the back of a 11,000 lb. dump truck.

Pickup PMA

Three crash tests were conducted: The first control test was without PMA and two additional tests with PMA's and 1,900 lb. and 4,400 lb. cars. The pickup PMA's tested were 5 ft. 6 in. long by 6 ft. 4 in. wide by 2 ft. 0 in. high.

It was concluded the lightweight TMA on the dump truck performed as well as heavier TMA's At 45 mph the occupants head impact velocity in the impacting vehicle ranged from 32 to 36 feet per second and vehicle damage was somewhat reduced form control tests without attenuators.

17. KEYWORDS
Attenuator, barrier truck, crash deceleration, honeycomb, impact tests, precrush, rear end collision, shadow truck

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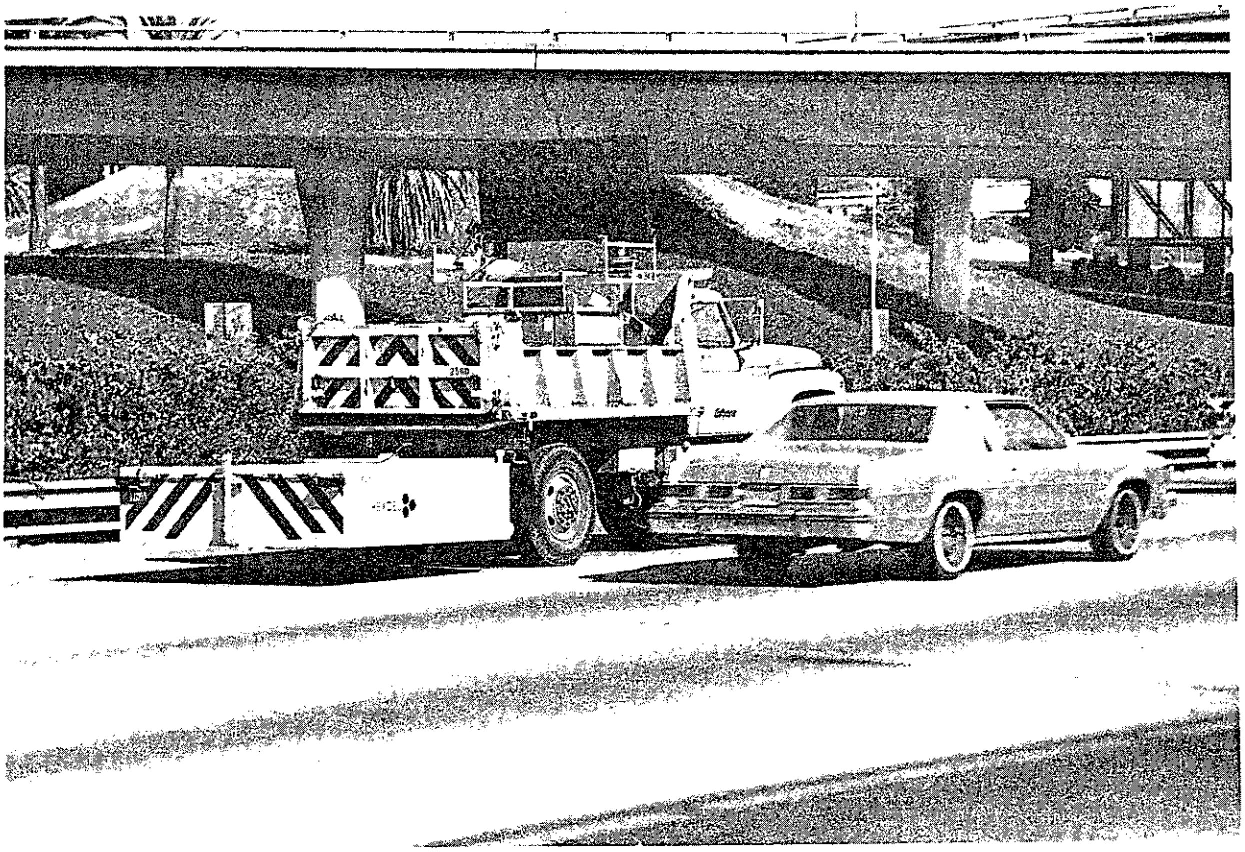

Final Report

Federal Research Grant No. D-4-163

DEVELOPMENT OF

A LIGHTWEIGHT TRUCK MOUNTED ATTENUATOR

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF EQUIPMENT MAINTENANCE AND DEVELOPMENT

DEVELOPMENT OF A LIGHTWEIGHT TRUCK MOUNTED ATTENUATOR

Study Made For. . . . . Division of Equipment Maintenance and Development

Study Made By . . . . Division of Equipment Maintenance and Development Transportation Laboratory

Under the Supervision of. . . Richard Ginsberg, P.E.
Eric F. Nordlin, P.E.

Principal Investigator. . . . John Marlow, P.E.

Co-Principal Investigator . . Calvin Schiefferly

Report Prepared By. . . . . . Calvin Schiefferly

Consultant. . . . . Roger Stoughton, P.E.

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The California Department of Transportation has implemented the use of TMA's on almost all highway maintenance operations involving slow moving or stationary vehicles.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
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NOTICE

The contents of this report reflects the views of the researchers who have endeavored to present accurate data and draw conclusions in a clear and objective manner.

The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Neither the State of California nor the United States Government endorse products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential to the object of this document.

CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quanity	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2) square feet (ft^2) acres	6.432×10^{-4} .09290 .4047	square metres (m^2) square metres (m^2) hectares (ha)
Volume	gallons (gal) cubic feet (ft^3) cubic yards (yd^3)	3.785 .02832 .7646	litres (l) cubic metres (m^3) cubic metres (m^3)
Volume/Time			
(Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour(mph) feet per second(fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity(G)	9.807	metres per second squared (m/s^2)
Weight Density	pounds per cubic (lb/ft^3)	16.02	kilograms per cubic metre (kg/m^2)
Force	pounds (lbs) kips (1000 lbs)	4.448 4448	newtons(N) newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds(ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds(ft-lbs) foot-pounds(ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi) pounds per square foot (psf)	6895 47.88	pascals (Pa) pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi $\sqrt{in}$)	1.0988	mega pascals $\sqrt{metre}$ (MPa $\sqrt{m}$)
	pounds per square inch square root inch (psi $\sqrt{in}$)	1.0988	kilo pascals $\sqrt{metre}$ (KPa $\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{tF - 32}{1.8} = tC$	degrees celsius (°C)

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Transportation Laboratory

Eric F. Nordlin: General Supervision. J. Robert Stoker: Technical Consultation. Roger Stoughton: Technical consultation, test supervision and general supervision. Jim Keesling: Test coordination, test preparation, data reduction, and movie report. Lee Wilson: Test preparation. Roy Steiner, Machine Shop: Vehicle (car) equipment installation and test preparation. Richard Johnson, Delmar Gans, William Ng, and Robert Caudle: Electronic instrumentation of test vehicles and dummy.

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Hexcel Corporation

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United Research and Manufacturing

Also, we appreciated the technical assistance from Bill Gottwald of United Research and Manufacturing.

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1. INTRODUCTION

1.1 Problem

Slow moving or parked trucks used to shadow or shield maintenance activities on a high speed highway pose a special safety problem. Even though signs, flashing lights, and traffic cones are carefully placed to warn the public, still inattentive motorists occasionally crash into the backs of the trucks. This problem caused accidents that have resulted in the deaths of Caltrans maintenance workers.

Caltrans is taking a number of corrective steps to mitigate this traffic problem. One measure taken was to use truck mounted attenuators (TMAs) for all vulnerable trucks. A TMA is a compact crash cushion which is suspended from the back of the truck. It is similar in concept to those placed in front of fixed objects at freeway offramps. The purpose of the TMA is to reduce damage to both the impacting vehicle and the maintenance truck and, particularly, to lessen the severity of injuries to passengers of either vehicle.

The TMAs available when this project began were heavy and reduced the payload capabilities of the truck. They were also cumbersome and difficult to remove from trucks.

1.2 Objectives

The Caltrans Division of Equipment Maintenance and Development is responsible for development/procurement of highway maintenance equipment for the California Department of Transportation.

The number of manufacturers involved in TMAs is very limited. This is due to their low demand and high development costs. Therefore, the Division of Equipment Maintenance and Development proceeded to develop a TMA using a suitable lightweight energy absorption material.

The objectives of this research were to develop two types of lightweight attenuators, one for a medium size dump truck (two axle, four cubic yard) and one for a three-quarter ton pickup.

The truck mounted attenuator (TMA) to be developed should provide the following improvements over units currently available:

1. Should not severely reduce the payload capability of the truck.

2. Should be easily removable and handled by one person.

3. Should provide a crash cushion equal to existing heavier TMAs.

The pickup mounted attenuator (PMA) to be developed should provide the following:

1. Should be a size adaptable to a pickup.

2. Should store in a position that will not affect the maneuverability of the pickup.

3. Should provide a safer working environment for the driver of the pickup.

4. Should improve the safety of occupants in vehicles that impact the PMA.

1.3 Background

A brief description of the four known existing types of TMAs follows:

The first TMA was developed and tested at the Texas Transportation Institute (TTI) in 1972. It consists of an array of empty 55 gallon steel drums, like those used in highway crash cushions. The drums are mounted on a simple one-axle trailer. The TMA is rigidly attached to the back of the truck and extends about 20 feet behind it. It has been tested successfully by a car impacting it at 60 mph.(1)*

* Numbers in parenthesis refer to a reference list at the end of this report.

A variation of the Texas design was first used in Ontario, Canada in 1975.[(2)] It performed well in two accidents. The long length of these TMA trailers makes them cumbersome to tow. There was further concern that the rigid TMA to truck connection could result in weld fatigue and excessive tire wear.

Transpo-Safety, Inc., of New Rochelle, New York manufactures a TMA called Cushion Safe. It consists of a cluster of water-filled, tubular vinyl cells which expel water through small holes in the top of the cells, and thus absorb energy during impacts. This unit has serious disadvantages due to its heavy weight and shallow collapse depth. The entire unit hangs from the truck and projects only about 28 inches beyond the back of it. Except for impacts at low speeds, accelerations would be too high for the safety of passengers. No rigorous crash testing has been performed on this unit.

The University of Connecticut developed a TMA using a row of veritcal steel pipe sections mounted on a sliding frame support. Four two-foot diameter by 34-inch high sections of pipe with wall thicknesses of 1/4-inch and 3/8-inch are used. Impacting vehicles strike an aluminum plate assembly at the back of the TMA which travels forward, successively crushing the four pipe sections. Maximum possible collapse distance for the TMA is about 8-feet; the TMA is hung from and projects back to a total of 9-feet 3-inches from the rear of the truck. This design was also rejected by Caltrans because of excessive weight and minimal ground clearance. A heavy TMA reduces the payload that a truck can carry while also serving as a protective "barrier". Subsequently the University of Connecticut reduced the weight of the aluminum impacting plate assembly from 430 to 278 lbs. Two crash tests were conducted by TTI in 1978.[(3)]

Energy Absorption Systems, Inc. (EAS) located in West Sacramento, California developed a TMA, which Caltrans used for a previous research project titled, "Vehicular Impact Tests of a Truck Mounted Attenuator Containing Vermiculite Concrete Cells".[(4)] After this research was concluded, Caltrans Division of Equipment Maintenance and Development procured 80 of these units and approximately 30 to 40 are still in use. These units have been involved in many accidents and performed well. The heavy weight of these units limits the truck they are mounted on to small loads.

Energy Absorption Systems, Inc. (EAS) has developed a lightweight TMA using a combination of paper honeycomb and polyurethane foam material encased in a fiber glass shell.

Accidents involving Caltrans maintenance vehicles have been frequent in recent years. In 1978 there were 64 accidents, 43 of which were rear end collisions. In most cases the Caltrans vehicle was a truck or pickup. The accidents have included Caltrans vehicles that were moving, were parked and occupied, or were parked with Caltrans workers in front of their vehicles.

2. CONCLUSIONS

The following conclusions were based on the results of twelve 45 mph passenger car impact tests into the back ends of dump trucks weighing about 11,700 lbs. and pickups weighing 5,000 lbs. Eleven of the twelve were shielded with TMAs and PMAs. The test results were judged in comparison with the appraisal standards in Transportation Research Circular No. 191(5) and National Cooperative Highway Research Program (NCHRP) Report 230(6). The three appraisal factors used to judge results were structural integrity, impact severity (or occupant risk), and vehicle trajectory.

2.1 Structural Integrity

1. Although damage to the impacting passenger car front ends was severe in all TMA tests, there was virtually no collapse or intrusion of the passenger compartment by vehicle or TMA components, except for slight intrusion in the angle test (Test 389). In a control test (Research Grant No. D-4-164, Test No. 371(4)) with no TMA, the front end crush of the car was much more severe and there was a slight intrusion of the car passenger compartment which would have increased at speeds over 45 mph.

2. There was no damage to the rear end of the truck/pickup in any test when mounted with an antenuator. The damage was extensive on truck/pickup when an attenuator was not used (Test 371 and Test 391).

3. Most or all of the aluminum honeycomb cells inside the TMA and PMA were effectively crushed in all tests. Debris from the crushed cells and aluminum skin enclosure was minimal.

4. There was no damage to the steel backup frame and mounting controls on the TMA and PMA in all tests except on the angle test (Test 389) when the steel backup plate was slightly deformed.

5. In all tests, the car had small values of pitch, roll, and yaw; hence, the penetration of the car into the TMA was controlled, and there was no instability of the car or truck.

2.2 Impact Severity

1. The impacting passenger car accelerations in the control test with no TMA (Test 371) were unacceptably high: -21.5 g's compared with a preferred maximum of -6 to -8 g's and a permissible maximum of -12 g's. (These values are for the highest 50ms average during impact)

2. The TMA lowered the car accelerations in the five head-on 4500 lbs. car tests to values of -11.4 to -14.4 g's. Thus, the TMAs and PMAs reduced the accelerations considerably, but reached their performance limit at impact speeds of 45 mph for the 4500 lb. cars.

3. Accelerations for a 2200 lb. car were less than the control test value. Three head-on 2200 lb. car tests results ranged from -15 to -16 g's. This indicates that unless the TMA design is revised, it can only meet acceleration standards at impact speeds <u>less</u> than 45 mph for lightweight and mini-weight cars.

4. When the TMA was struck offset and at an angle, by a 4500 lb. car at 45 mph, the car accelerations were -10.6 g's.

5. In tests with the final TMA design the theoretical values of dummy-head relative velocity, when striking the car windshield after two feet of travel, were 32.4 to 34.5 feet per second (4,500 lb. car) and 35.6 feet per second (2,200 lb. car). NCHRP Report 230 recommends maximum limit values of 40fps and design limit of 30 fps. These test results indicate that the TMA would be most beneficial if car passengers were wearing lap belts and shoulder belts at impact speeds of 45 mph.

6. Truck accelerations were relatively low, 2.4 to 4.3 g's for the TMA tests and 5.4 to 7.7 g's for the PMA tests. Caltrans has installed head restraints in all trucks with attenuators to minimize driver injury.

7. The PMA did not reduce accelerations significantly (8.3 to 6.3, 4,500 lb. car and 12.4, 1,800 lb. car). However, the damage to the pickup and cars was significantly reduced.

2.3 Vehicle Trajectory

1. The trucks, which were all in second gear and had rear wheels braked, traveled relatively short distances ahead after impact by the passenger cars at 45 mph. The cars followed closely behind. This would cause minimal effect on adjacent traffic.

2. The roll ahead distances for the trucks were not affected by the TMA.

2.4 General

The lightweight TMA performed similarly and did not reduce "g" levels below the levels recorded in tests with heavier units containing vermiculite concrete cells presently in use. The benefits include debris free impact area, lightweight (allowing more payload in truck), and ease of handling and removal.

The lightweight PMA provided a safer atmosphere for a driver of a maintenance pickup in a shadow operation and for occupants of an impacting vehicle. The final PMA design was a reasonable size and the unit could be easily rotated to a position onto the pickup bed.

3. RECOMMENDATIONS

1. The TMA should be installed on slow moving or parked Caltrans trucks and heavy maintenance vehicles that are susceptible to rear end impacts.

2. Users of the TMA and their supervisors should be carefully informed about the capabilities and the limitations of the TMA.

3. Trucks equipped with attenuators should have headrests installed.

4. PMAs should be installed on pickups that are used for shadow operations and as lookout pickups.

4. IMPLEMENTATION

Caltrans implemented the use of TMAs in 1979 when eighty units were purchased. These vermiculite concrete units were built by Energy Absorption Systems, Inc.[4] of Sacramento, California. The use of TMAs expanded in 1981 when the department purchased four hundred and thirty (430) units. These units were purchased by competitive bidding on a specification. The specification covered various performance, structural and miscellaneous criteria. Hexcel Corporation of Dublin, California was the low bidder. The TMA described in this report is very similar to the units purchased from Hexcel Corporation.

Presently there is only one PMA in use as a prototype. There are plans for two additional units to go into service. The PMAs are used in areas where maneuverability of the vehicle is important.

Caltrans developed guidelines for the use of TMAs. Caltrans Maintenance Manual, Chapter VIII, Protection of Workers states the following in regard to TMAs:

"**8.05 Protective Vehicles**

There are three classes of protective vehicles: Shadow, Barrier, and Advance Warning.

1. Shadow Vehicle:

This is a moving vehicle a short distance from a moving operation, giving physical protection from traffic.

A shadow vehicle shall:

a. Carry an attenuator, and
b. on multilane roads, carry an arrowboard operating in the "arrow" mode.
c. On two-lane roads, carry either an arrowboard operating in the "caution" mode or a flashing amber light.

The protective ability of a shadow vehicle is directly proportional to its weight; the heavier the better. There is no value in using pickup trucks as shadow vehicles, especially when they are intended to protect something heavy like a sweeper. Not only do they offer little protection, but the driver is severely exposed.

The minimum size for a shadow vehicle on the traveled way is a two-ton truck.

The purpose of a shadow vehicle is to run physical interference against traffic for a work vehicle and its crew immediately downstream. In this exposed position the most important factor in protecting the driver of the shadow vehicle is the mass of the vehicle itself. A four-yard dump truck doesn't move much when it is hit by a car. We also need an arrowboard or a flashing amber light to alert drivers who are inattentive or intoxicated. The attenuator absorbs kinetic energy, softening the blow to our driver and usually saving the life of the motorist. The headrest protects the driver's head and neck, and the seat belt prevents being thrown forward.

2. Barrier Vehicle:
A barrier vehicle is parked in advance of a stationary operation. It should be unoccupied when parked. Use as heavy a vehicle as is reasonably available. Its purpose is to protect workers on foot from being hit by vehicles leaving the traveled way. It must be carefully positioned so that it will intercept errant vehicles, but will not roll ahead and run over workers. Roll ahead may be controlled by proper brakes, sufficient space, and angle parking. The barrier vehicle may be parked at various angles, including perpendicular to the lane. When parked at an angle, the front of the barrier vehicle should be pointed away from traffic to avoid driver panic and to prevent secondary collisions if the barrier vehicle is hit and pushed ahead. Front wheels should be turned away from the work zone.

As stated in Section 8.07, it is not required that barrier vehicles have arrowboards. Neither is it required that they have attenuators. It is however, required that attenuators be used when they are available. When equipped with an attenuator, the vehicle must be parked parallel with traffic. Obviously, when parked at an angle, neither an arrowboard nor an attenuator would be functional.

Any vehicles, including barrier vehicles, used to shadow the placement and retrieval of laneclosure devices from the traveled way of multilane roads shall have both arrowboards and attenuators.

3. Advance Warning Vehicle:
This vehicle is stationed a considerable distance upstream of a moving or stationary operation. Its purpose is to display sign messages which will advise motorists of what to expect ahead. On the shoulder it shall operate an

arrowboard in the "caution" mode, or a flashing amber light. If it encroaches on a freeway lane, it shall operate an arrowboard in the "arrow" mode and shall be fitted with an attenuator. An illuminated matrix-type changeable message sign may be used instead of an arrowboard.

8.06 Attenuators

Our intent is to provide those who occupy slow vehicles in traffic lanes with as much protection as can reasonably be applied without making it too difficult for them to do their work. The main devices we use are the arrowboard, the headrest, the seat belt, and the truck-mounted attenuator. The arrowboard and the attenuator serve also to protect the public.

Provisions regarding attenuators are not intended for city streets or other low-speed conditions. However, they may be used there at the option of the supervisor.

Any stationary or slow-moving, unshadowed vehicle working in a freeway traffic lane outside a lane closure shall carry an arrowboard and an attenuator. This requirement does not apply to specialized vehicles which are unsuited to mounting or using such devices, such as motor graders, snow removal equipment and tow trucks. In the absence of an arrowboard, a flashing amber light or a light bar shall be used.

Although an attenuator reduces the stresses on vehicles and their occupants in a collision, it does not reduce the distance that a truck will roll or slide ahead when struck from behind. For example, in two Caltrans tests, an 11,600 pound truck with front and rear brakes locked, on dry pavement, was struck directly in the rear by a standard sedan at 45 mph. It moved forward 10 feet without an attenuator, and 10 feet with an attenuator.

The proper position of a protective vehicle with respect to those it protects must be carefully judged. If too close, the protective vehicle may hit the workers; if too far back, traffic may go around it and hit the workers. See Table 8-1 for data which may be helpful in choosing size and placement of protective vehicles. Where available, two or more protective vehicles may be used to reduce this risk."

5. TECHNICIAL DISCUSSION

5.1 Test Conditions

5.1.1 Test Facility

All vehicular impact tests on the lightweight TMA were conducted at the Caltrans Dynamic Test Facility in Bryte, California near Sacramento. The tests took place on flat asphalt concrete paved surfaces. The weather was clear and mild for all tests.

5.1.2 Lightweight Truck Mounted Attenuator Design

The lightweight TMA design consisted of steel mounting hardware, aluminum honeycomb attenuator, rear taillights and three screw jacks with casters. See Figure 1 for configuration.

The energy absorbing component of the TMA was Hexcel® aluminum honeycomb. The Hexcel aluminum honeycomb material was chosen for this application for the following reasons: Lightweight, ability to withstand moisture, low cost, ease of construction, and flexibility in adjusting the volume to attain the most desired crash test results.

The attenuator cell without mounting hardware weighed 280 pounds and mounting hardware weighed approximately 400 pounds. The overall size was 7-feet 8-inches wide, 7-feet long and 2-feet high.

The mounting hardware provided for easy removal of the attenuator and backup structure, with two jacks (with caster wheels) on the foreend and one on the rearend of the attenuator. The entire unit could be disconnected and rolled away in five minutes or less.

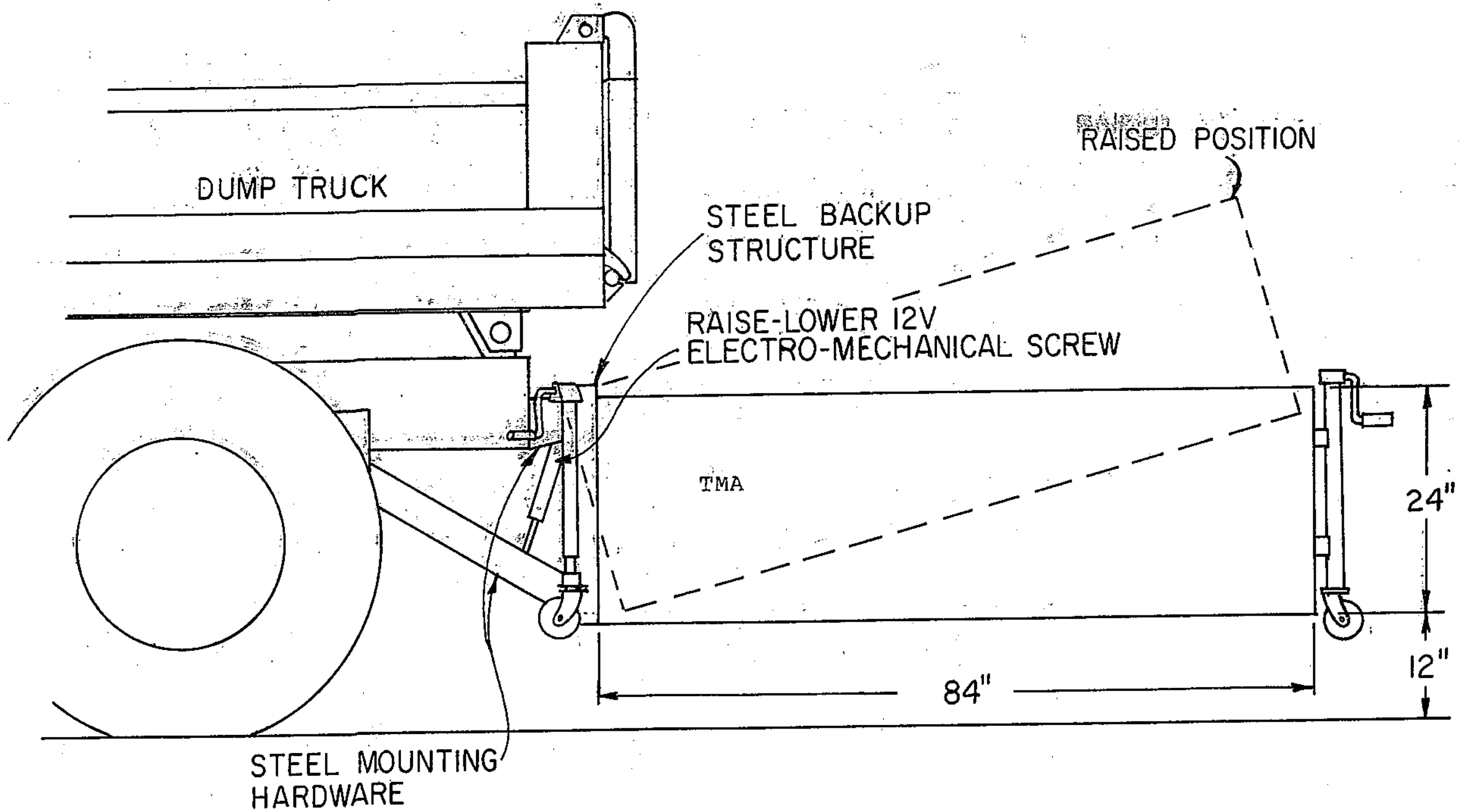

DUMP TRUCK
STEEL BACKUP STRUCTURE
RAISED POSITION
RAISE-LOWER 12V ELECTRO-MECHANICAL SCREW
TMA
24"
12"
84"
STEEL MOUNTING HARDWARE

FIGURE 1

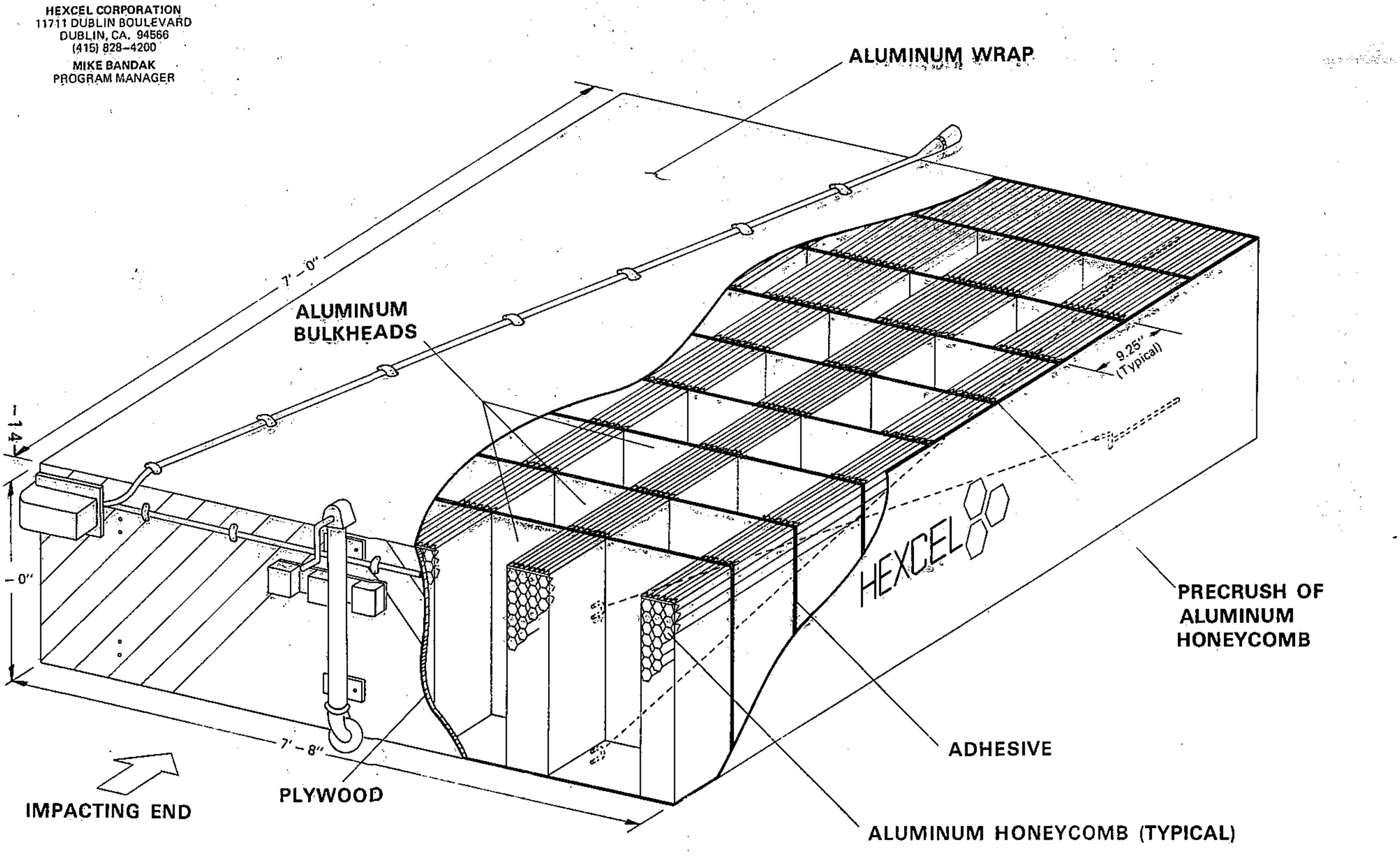
Aluminum Honeycomb Energy Absorption Cell (TMA):

The following TMA cell description is based on the final acceptable design. Through the impact testing, the TMA developed into 9 sections totaling in length, 84 inches. Separating each section was a bulkhead of .032-inch aluminum with a .75-inch thick plywood on the impact end, performing as a diaphragm during a collision. The cells and bulkhead were bonded together with Hexcel HP-326™ adhesive. The total length of 84-inches included the 9 bulkheads, .75-inch plywood diaphragm, and the honeycomb aluminum cells. The completed TMA included a complete wrap of .020-inch thick aluminum to enclose the assembly. See Figure 2.

Hexcel CR III®.375-5052-.0007N-1.0 Aluminum honeycomb was used for the cell blocks. This material had a static crush strength of 25 pounds per square inch and a dynamic crush strength of 30 pounds per square inch. It weighed 1.0 pound per cubic foot.

All cells in each section were 24-inches high (top to bottom) and there were 6 cells in each section, except for the last section, which was one cell running the full width of the TMA. See Figure 3 for cell layout in each section by test number.

As shown in Figure 3, the cell area progessively increased as the impacting car penetrated the TMA. This concept was developed to provide a suitable TMA for both 4500 pound and 2200 pound vehicles. Also, all honeycomb aluminum cell blocks were precrushed from 9.75-inch to 9.25-inch to remove the compressive peak that is required to start the constant stress level desired for the TMA.



TMA ENERGY ABSORPTION ASSEMBLY

FIGURE 2

ALUMINUM HONEYCOMB CELL BLOCK ARRANGEMENT AND AREA

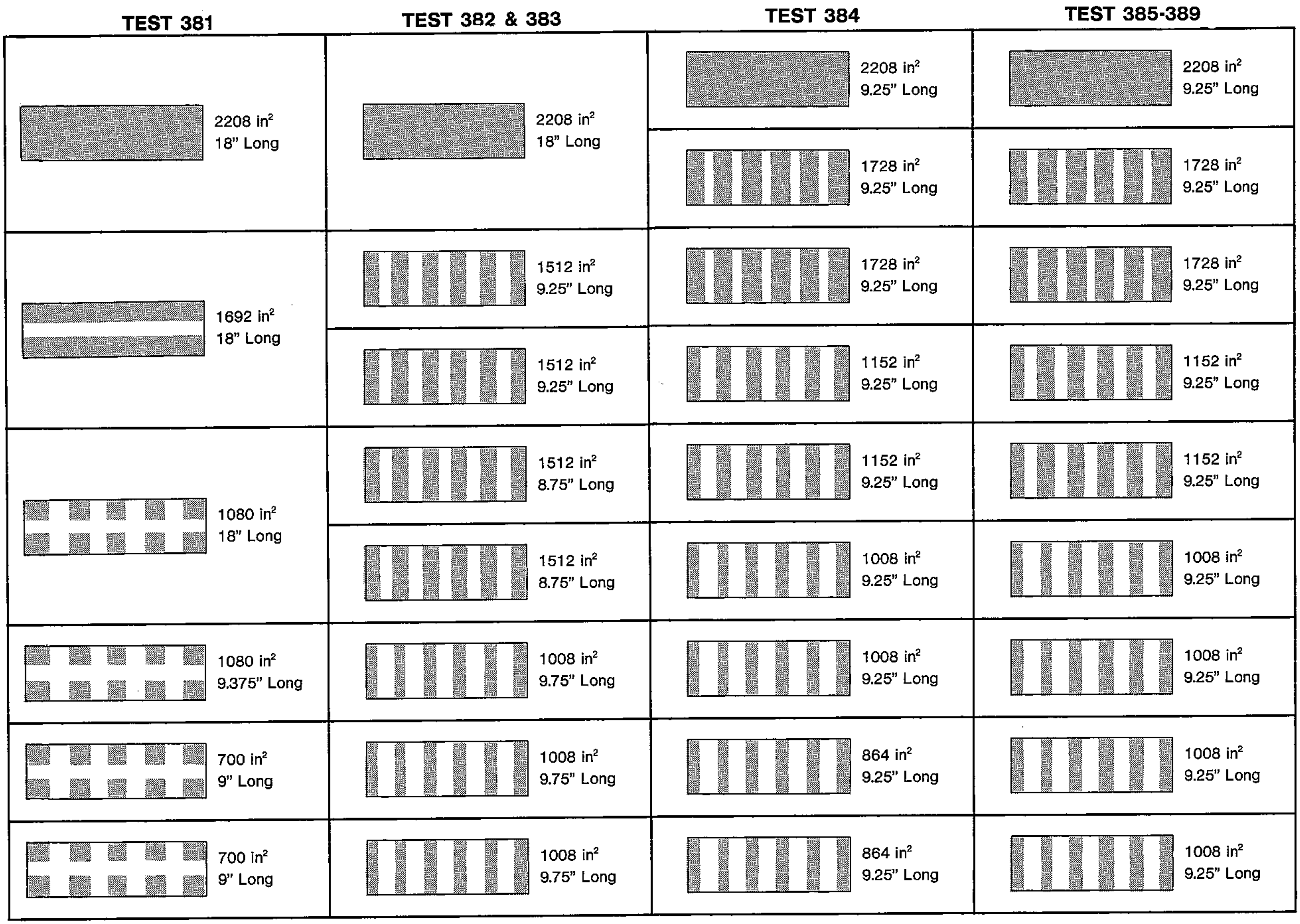


FIGURE 3

HONEYCOMB CELL BLOCKS

For a starting configuration cell, the initial TMA design was based on Kinetic energy of the impact at 45 mph (66 feet per second).

The following formulas were used for determining the volume of honeycomb and the length of the TMA cell.

$$KE_{car} = 1/2\ MV^2 = 1/2\ \frac{WV^2}{g}$$

KE = foot pounds
M = car mass slugs
V = feet per second

$$KE_{car} = 1/2\ \frac{4500}{32.2}\ (66)^2$$

$$KE_{car} = 304{,}379 \text{ ft. lbs.}$$

Speed of car and truck after collision

$$^{*}(MV)_{\substack{Truck\\Car}} = (MV)_{Car} + (MV)_{Truck}$$

$$\text{Since } M = \frac{W}{g}$$

$$V_{\substack{Truck\\Car}} = \frac{(WV)Car + (WV)Truck}{W\ Truck + W\ Car}$$

$$V_{\substack{Truck\\Car}} = \frac{(4500)(66) + (11000)(0)}{4500 + 11000}$$

$$V_{\substack{Truck\\Car}} = 19 \text{ fps}$$

$$KE_{\substack{Truck\\Car}} = 1/2\ \frac{4500 + 11000}{32.2}\ (19)^2$$

$$KE_{\substack{Truck\\Car}} = 86{,}886 \text{ ft. lb.}$$

$$KE_{impact} = KE_{car} - KE_{truck/car}$$

$$KE_{impact} = 304{,}379 - 86{,}886$$

$$KE_{impact} = 217{,}493 \text{ ft. lbs.}$$

* Based on the assumption of an inelastic collision and conservation of momentum.

To determine the overall length of the TMA an impact limit of 12 g's was used.

L = Length of TMA
Crush to Limit impact to 12 g's

217493 ft. lbs. = KE of impact (4500 lb. car)

$$L = \frac{217493}{12(4500)}$$

L = 4.03 ft.

Some kinetic energy would be expended in the crushing of the car. This would reduce the required stroke length, L.

The same calculations for a 2200 pound car resulted in figures of:

KE of impact = 124,006 ft. lbs.
L = 4.7 ft.

As seen by the calculations, the kinetic energy of the 2200 lb. vehicle impact was approximately one-half of the large car but the impact length was about equal, limiting the impact to 12 g's.

Based on the 4.7 feet required to limit impact to an average of 12 g's and the experience of using TMAs of 6-feet long (heavy vermiculite units in use by Caltrans), it was determined a maximum length of 7-feet for the TMA would be feasible. This would allow a longer crush length to improve the performance of the TMA for light and heavy cars.

The aluminum honeycomb when crushed perpendicular to the honeycomb cell has a maximum stroke of 80% of its original length. TMA of 7-feet has an overall stroke length of

7ft. x 80% = 5.6 ft.

Variables of the impacts (light vehicle and heavy vehicle) when considering the length of TMA crush were: Frontal area of vehicles and crush length on front of vehicles were unknowns. Impact test would determine how the aluminum honeycomb TMA performed.

By using the crush strength of the honeycomb and Kinetic Energy (K.E.) involved in the impact, a determination could be made as to the volume of honeycomb in the TMA. The problem of satisfying both heavy and light vehicle impacts and other variables required changes to the initial configurations. (See Figure 3 for Cell Block Changes)

For a starting configuration for Test 381 the following TMA cell was used. (See Figure 3 for TMAs by Test No.)

TMA USED IN TEST 381

Cell Block Length (Ft.)	Cell Block Area (Inch)^2		Dynamic Crush (PSI)		Stroke 80% (Cell Block Length) Feet		Energy Absorption Capability (ft.lbs)
1.5	2208	X	30	X	1.2	=	79,488
1.5	1692	X	30	X	1.2	=	60,921
1.5	1080	X	30	X	1.2	=	38,880
.75	1080	X	30	X	.6	=	19,440
.75	700	X	30	X	.6	=	12,600
.75	700	X	30	X	.6	=	12,600
6.75	Total Crush Length			=	5.4		
						TOTAL	223,920 ft.lbs.

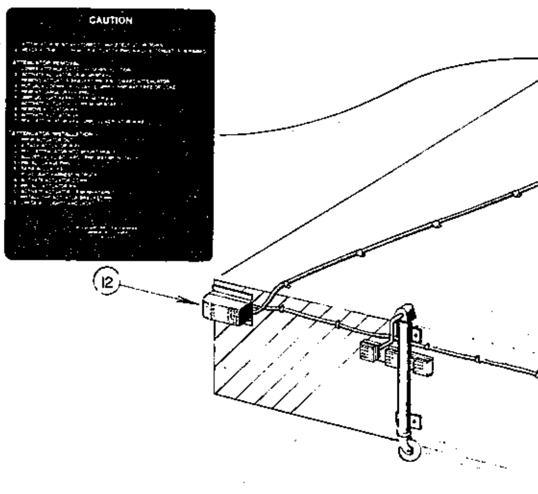
Steel Backup Mounting Frame: The vertical steel backup structure was next to the front of the TMA cell. It formed a strong plane of reaction against which the TMA cell was to be crushed and was not expected to deform. It also performed as a mounting structure for the TMA cell and provided attachments for mounting the TMA to the truck.

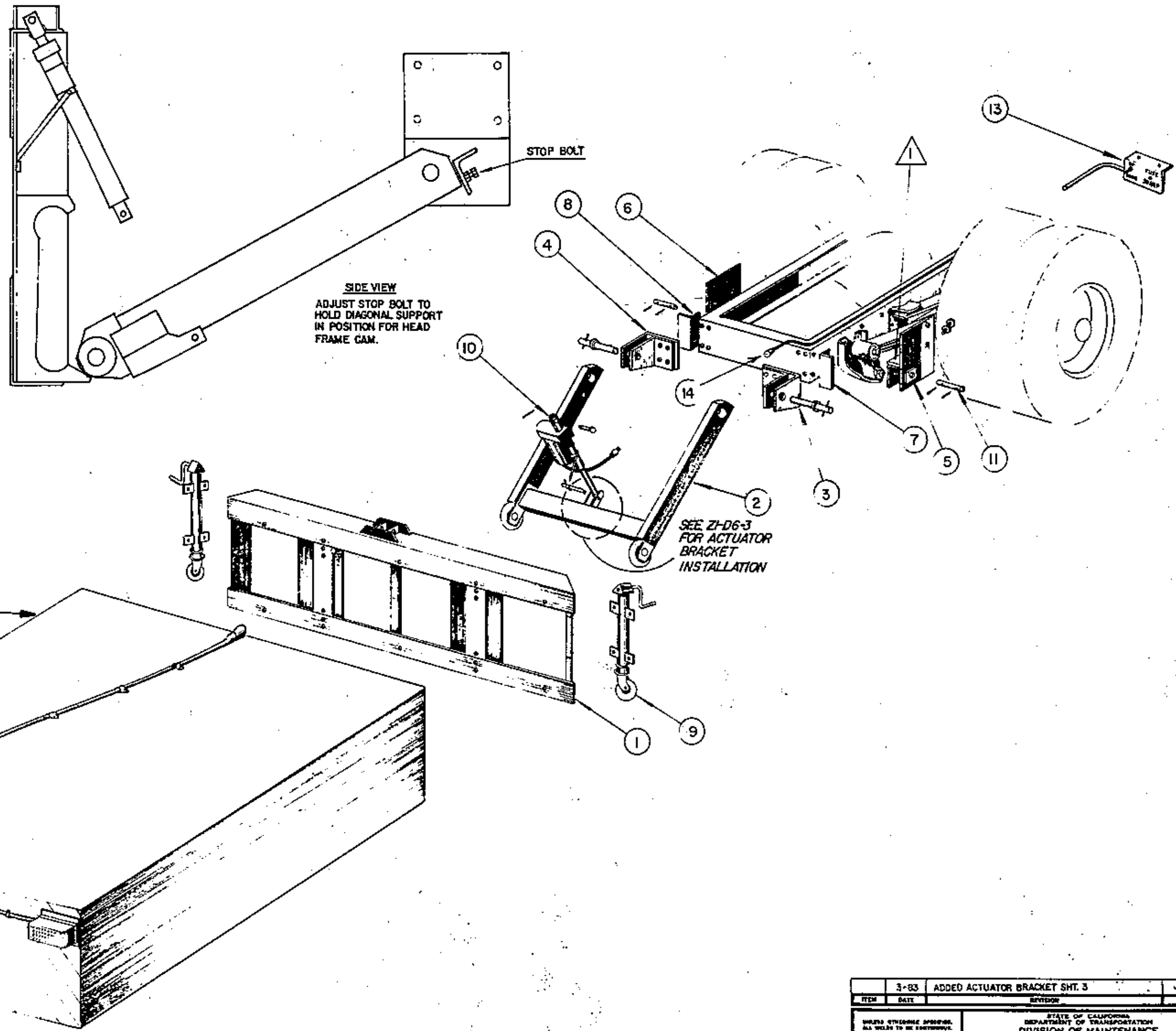
Three hand crank jacks with caster wheels were installed. Two were mounted on the front side of the steel mounting frame and one was mounted on the center rear of the TMA cell to assist in removing the TMA from the truck.

The mechanism to raise the attenuator consisted of a 12-volt electro mechanical screw that when activated would raise the rear of the attenuator up 15 degrees from the attenuator's normal horizontal position. This provided for clearance for driveways, etc. See Figure 4 and 5 for TMA assembly.

ATTENUATOR INSTALLATION PROCEDURE

1. CHECK PARTS LIST (ALL PARTS MUST BE ON HAND TO COMPLETE INSTALLATION). (VENDOR SUPPLIED)
2. MEASURE BOTTOM OF TRUCK FRAME TO FLOOR FOR 30". IF LOWER THAN 30" JACK UP TRUCK FRAME TO CLEAR FIXTURE (P1-D53-1)
3. REMOVE GUSSETTS, BRACKETS OR OTHER INTERFERRING PIECES ON REAR FRAME AREA.
4. REMOVE REAR WHEELS AND RESET TRUCK FRAME HEIGHT AS IN #2.
5. MOUNT ITEMS – 3 – 4 – 5 & – 6 TO ALIGNING FIXTURE (P1-D53-1) WITH PINS IN THE CORRECT POSITION AND ROLL INTO POSITION UNDER FRAME OF TRUCK.
6. CLAMP ITEMS – 3 – 4 – 5 & – 6 TO FRAME AND RELIEVE OR SHIM AS NEEDED.
7. DRILL 17/32 DIA. HOLES THROUGH FRAME AND BOLT IN PLACE.
8. PULL PINS AND REMOVE FIXTURE.
9. CLAMP ITEMS – 7 & – 8 (ANGLE IRON) TO FRAME, DRILL 17/32 DIA. HOLES AND BOLT TO FRAME.
10. WELD ITEMS – 3 – 7 AND – 4 – 8 TOGETHER.
11. INSTALL THE DIAGONAL BRACE (ITEM – 2) WITH HINGE PINS. (ITEM-11)
12. INSTALL THE HEAD FRAME (ITEM 1) WITH HINGE PINS.
13. ADJUST STOP BOLTS AT FWD. BRACKETS FOR CORRECT DIAGONAL BRACKET ENGAGEMENT OF CAM AREA.
14. INSTALL ACTUATOR (ITEM 10) WITH THE PINS IN HEAD FRAME AND DIAGONAL BRACE.
15. INSTALL WIRE HARNESS (ITEM – 14) AND SWITCH (ITEM – 13) IN CAB AND CONNECT TO BATTERY AND GROUND.
16. PLUG IN ACTUATOR AND IF ACTUATOR DOES NOT RUN OR OPERATES IN WRONG DIRECTION, REVERSE PLUG.
17. CAUTION — REMOVE PINTLE HOOK IF REQUIRED.
18. TEST RAISING MECHANISM BEING SURE OF NO OBSTRUCTIONS.
19. ATTACH ATTENUATOR TO HEAD FRAME WITH 18 LOCK-NUTS.
20. ATTACH (3) HAND JACKS TO ATTENUATOR.
21. ATTACH TAIL LIGHTS TO ATTENUATOR AND SECURE WIRE HARNESS TO ATTENUATOR.





	3-83	ADDED ACTUATOR BRACKET SHT. 3	J.C.W.
ITEM	DATE	REVISION	BY

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE
OFFICE OF EQUIPMENT

TMA BACK SUPPORT INSTALLATION

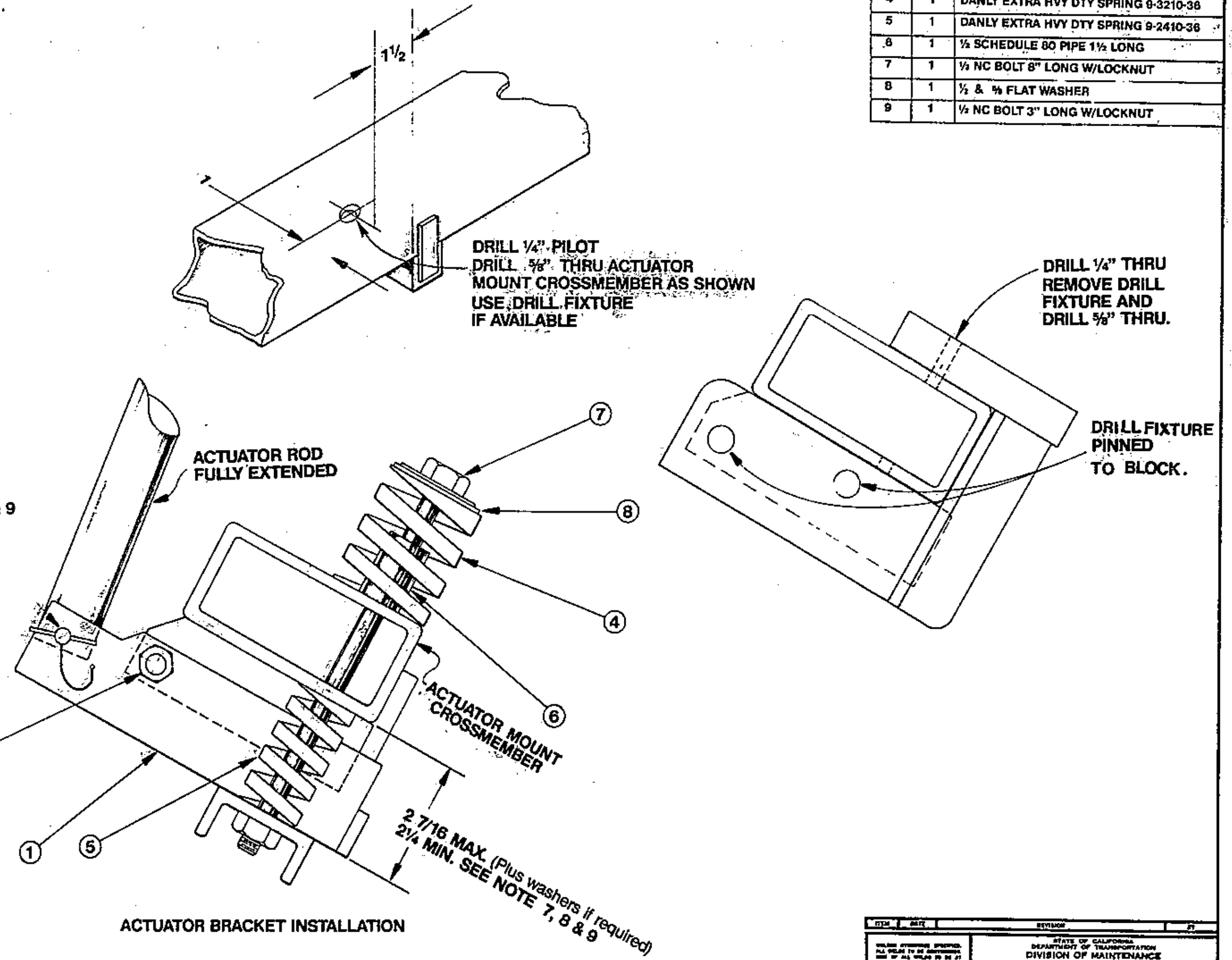
SCALE NO SCALE | DATE FEB. 1982 | Z1-D6-2
DRAWN J. WON
SHEET 2 OF 3 SHEETS

TMA ASSEMBLY

FIGURE 4

INSTALLATION

1. Remove attenuator from truck.
2. Remove existing lower actuator bracket.
3. Drill ⅝" dia as shown.
4. Install new bracket as shown.
5. Torque nut down to compress lower spring length to 2 7/16".
6. Mount attenuator, run actuator out completely.
7. Actuator pin hole and bracket pin hole should align so that pin can be easily removed or installed. When actuator is fully extended. If not aligned see note 8 or 9
8. To lower bracket pin hole for alignment tighten bolt to compress lower spring. This will lower hole location. Do not compress spring less than 2¼ inches. If this is necessary pin hole must be relocated for proper alignment. This may be done by filling pin hole in with weld and redrilling.
9. To raise pin hole add ½" flat washers with lower spring.



ACTUATOR BRACKET INSTALLATION

MATERIALS

ITEM	QUAN.	DESCRIPTION
1	1	WELDED ASSY SEE DWG. PZ-63-1
4	1	DANLY EXTRA HVY DTY SPRING 9-3210-38
5	1	DANLY EXTRA HVY DTY SPRING 9-2410-38
6	1	½ SCHEDULE 80 PIPE 1½ LONG
7	1	½ NC BOLT 8" LONG W/LOCKNUT
8	1	½ & ⅝ FLAT WASHER
9	1	½ NC BOLT 3" LONG W/LOCKNUT

STATE OF CALIFORNIA
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DIVISION OF MAINTENANCE
OFFICE OF EQUIPMENT
HEXCEL ATTENUATOR
ACTUATOR BRACKET

SCALE NO SCALE | DATE MAR 1983 | Z1-D6-3
DRAWN J. WON

TMA ACTUATOR BRACKET

FIGURE 5

5.1.3 Lightweight Pickup Mounted Attenuator (PMA) Design

The energy absorbing component of the pickup attenuator was Hexcel aluminum honeycomb, the same as the TMA.

The attenuator cell without mounting hardware weighed approximately 200 pounds. The overall size was 6-feet 4-inches wide, 5-feet 6-inches long and 2-feet high. The mounting hardware weighed approximately 400 pounds.

As with the TMA, the PMA consisted of a steel backup mounting frame that fully supported the PMA as it was impacted. The frame also performed as a mounting structure for the attenuator cell. See Figure 6 for PMA configuration.

Aluminum Honeycomb Energy Absorption Cell (PMA): As with the TMA, the PMA incorporated Hexcel CR III .375-5052-.007N-1.0 aluminum honeycomb for the cell blocks. The dynamic crush strength of this material is 30 pounds per square inch.

The PMA design was based on KE of impact of 4500 and 2200 pound car impacts with a pickup of 6000 pounds at speeds of 45 mph.

KE car (4500 pounds) = 304,379 foot pounds

$$V_{\substack{\text{Pickup}\\\text{Car}}} = \frac{(WV)\text{Pickup} + (WV)\text{Car}}{W\ \text{Pickup} + W\ \text{Car}}$$

$$V = \frac{(6000)(0) + (4500)(66)}{6000 + 4500}$$

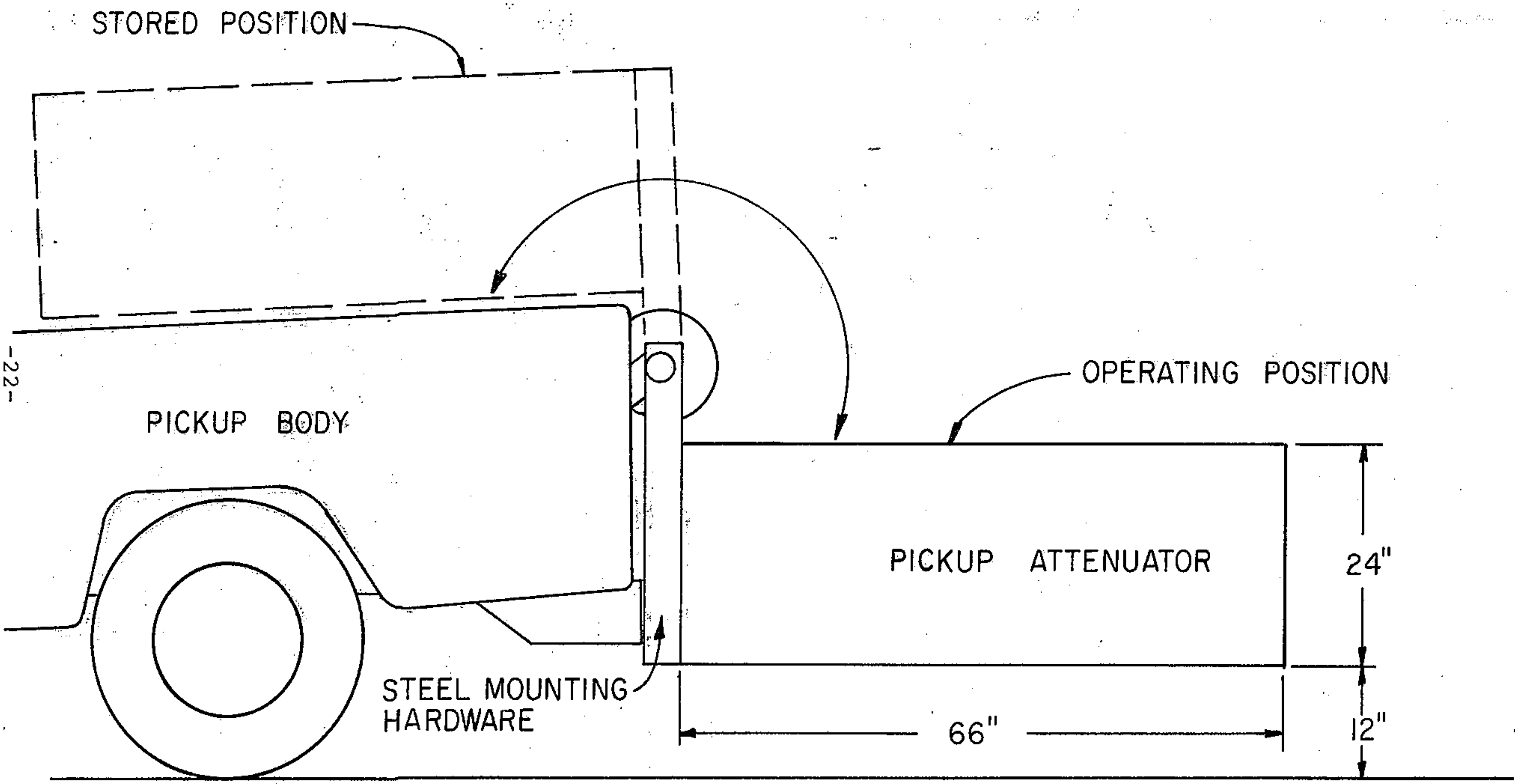
$$V = 28\text{fps}$$

$$KE_{\substack{\text{Pickup}\\\text{Car}}} = 1/2\ \frac{6000 + 4500}{32.2}\ (28)^2$$

$$KE_{\substack{\text{Pickup}\\\text{Car}}} = 127{,}826 \text{ ft. lbs.}$$

$$KE\ \text{impact} = KE\ \text{Car} - KE_{\substack{\text{Pickup}\\\text{Car}}}$$

$$KE\ \text{impact} = 176{,}553 \text{ ft. lbs.}$$



PICKUP MOUNTED ATTENUATOR

FIGURE 6

To determine the overall length of the PMA an impact limit of 12 g's was used.

L = Length of PMA crush to limit impact to 12 g's
176,553 = KE of impact 4500 pound car

$$L = \frac{176553}{12(4500)}$$

L = 3.27 feet

The same calculations for a 2200 pound car resulted in figures of

KE of impact = 108,915 foot pounds
L = 4.12 feet

Based on the 80% crush stroke of the aluminum honeycomb the greater length of 4.12 feet for the 2200 pound vehicle was used to determine the length of the PMA.

$$80\%(L_1) = 4.12 \text{ feet}$$

$$L_1 = 5.15 \text{ feet}$$

By using the KE of the impacts and length required to limit impact to 12 g's(L) a PMA cell block design was developed.

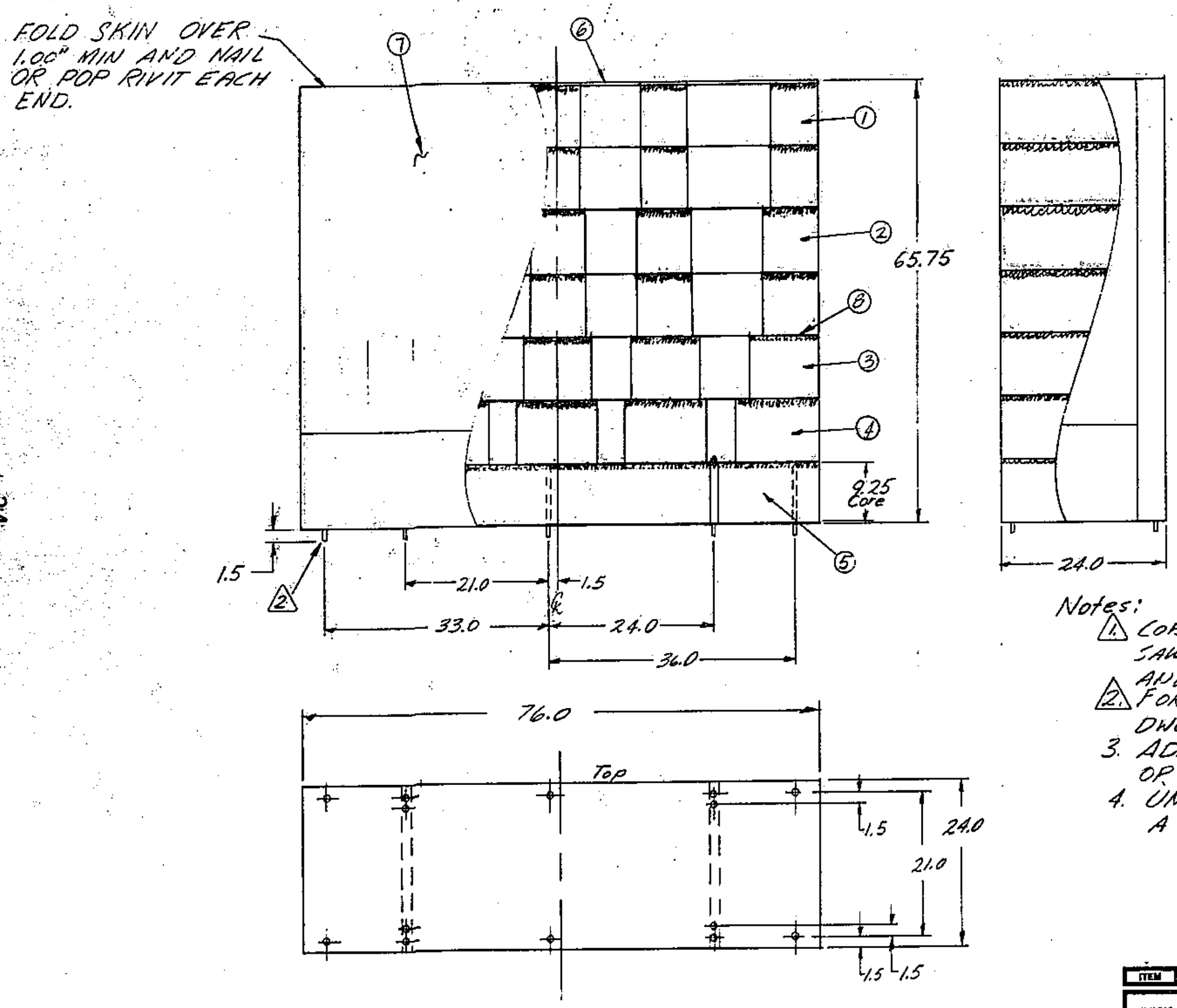
PMA used in tests 392 and 393 is shown in Figure 7.

Steel Backup Mounting Frame: The vertical steel backup structure was next to the front of the PMA cell. It formed a strong plane of reaction against which the PMA cell was to be crushed and was not expected to deform. It also performed as a mounting structure for the PMA cell to the pickup.

Incorporated into the mounting frame of the PMA was a hydraulic actuated mechanism that rotated the PMA cell onto the pickup body, for a store position.

See Figures 8 thru 11 for PMA steel backup mounting frame design.

Item	Quan	Description
1	10	7×24 CORE △1
2	"	8×24 " "
3	5	10×24 " "
4	5	12×24 " "
5	1	76×24 " "
6	1	24×76×3/4 AC Exterior Plywood
7	As Required	.020 Thk 3003-H14 Skin
8	7	24×76×.030-5052 Alum-Bulkhead



Notes:
1. CORE TO BE CR III 3/8 5052-.0007N-1.0* SAW SLICES TO 9.75" ±.030, EXPAND AND PRE CRUSH TO 9.25" Loc.
2. FOR MOUNTING STUD DETAIL & PARTS SEE DWG HD4-3003, SECTION C-C (HEXCEL DWG)
3. ADHESIVE TO BE F-185/1659 HEXCEL OR HP 326.
4. UNIT TO BE PAINTED WITH A LIGHT COLORED FLAT PRIMER.

ITEM	DATE	REVISION	BY

UNLESS OTHERWISE SPECIFIED, ALL WELDS TO BE CONTINUOUS. SIZE OF ALL WELDS TO BE AT LEAST HALF THE THICKNESS OF THE THINNER OF THE ADJACENT METALS.

TOLERANCE—UNLESS OTHERWISE SPECIFIED.
DECIMAL ± .06
FRACTIONAL ± —
ANGULAR ± —

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OFFICE OF EQUIPMENT

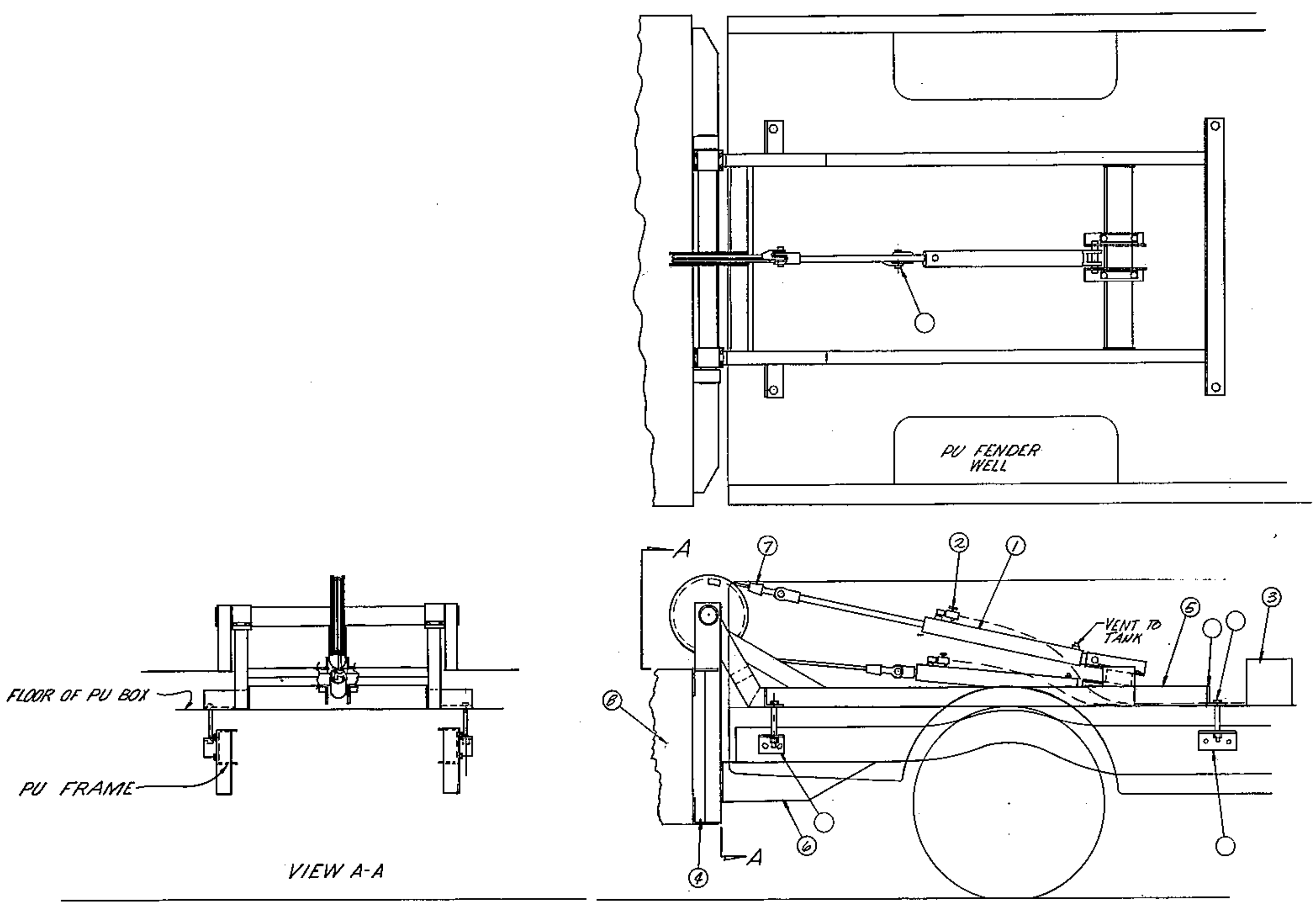
LIGHTWEIGHT PICKUP MOUNTED ATTENUATOR

SCALE — DATE 2/19/81
DRAWN G.L.S. FILE
CHECKED APPROVED
392-1
SHEET 1 OF 1 SHEETS

PICKUP ATTENUATOR

PRINTED ON DIEPO NO. 1000H CLEARPRINT 4/76

FIGURE 7



BILL OF MATERIAL

ITEM	QUAN	DESCRIPTION
1	2	HYDRAULIC CYL BCC2520W PAUL MONROE
2	2	FLOW CONTROL VALVE FREE/FLOW CONTROL/FLOW
3	1	MONARCH HYD PUMP W/4WY SOL VALVE
4	1	BACK UP 1-2 ASSY
5	1	MOUNT -4 ASSY
6	2 R L	BRACKET 7-3 ASSY
7	1	CABLE 6-3 ASSY
8	1	HEXCEL ATTENUATOR

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PICKUP ATTENUATOR MOUNTING ASSY

SCALE NONE

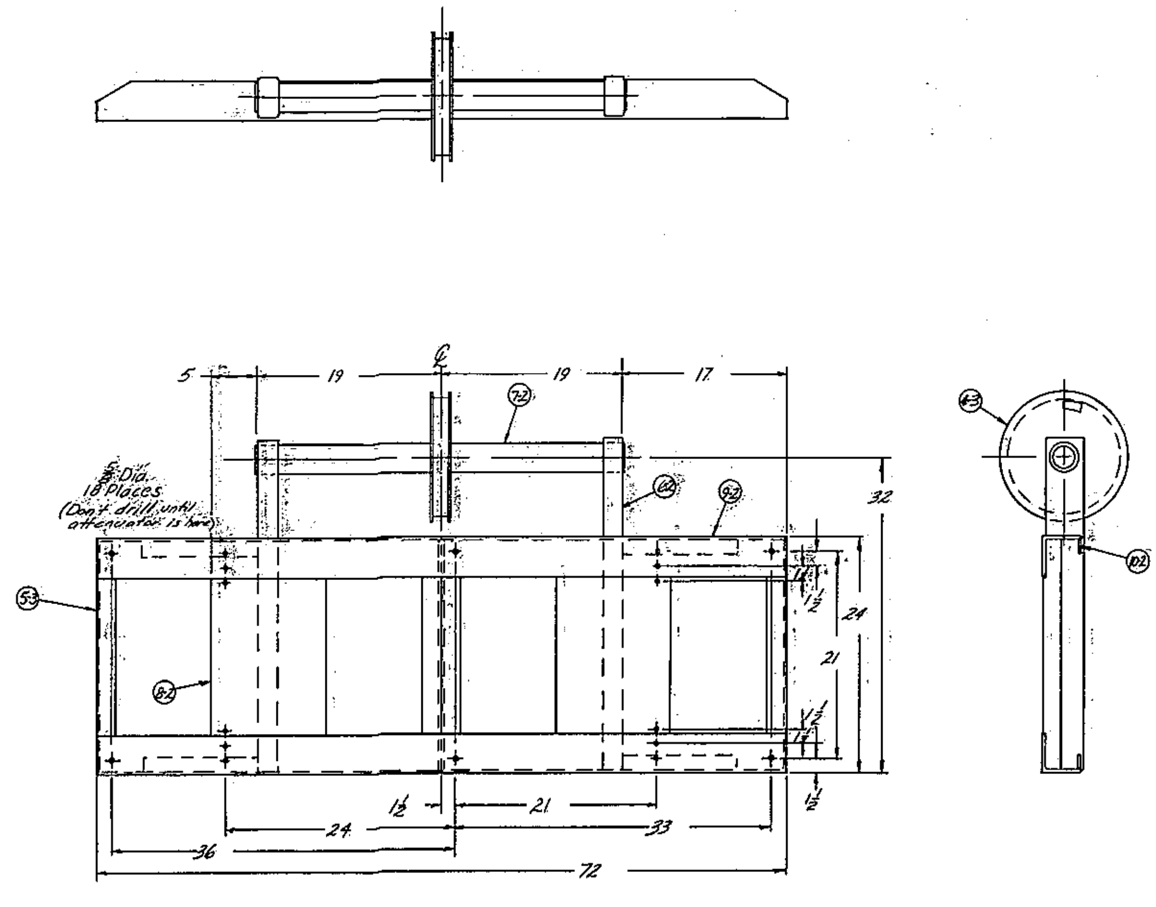
-1

PICKUP MOUNTED ATTENUATOR HARDWARE

FIGURE 8

BILL OF MATERIAL

ITEM	QUAN	DESCRIPTION
1-2	1	TO BE WELDED ASSY. OF FOLLOWING
4-3	1	CABLE DRUM SEE 1-3
5-3	4	ANGLE SEE 5-3
6-2	2	2" x 4" x 1/4 WALL x 33 3/4 LG. RECT. MECH. TUBING
7-2	1	3" O.D. x 2.25 I.D. x 38 LG ROUND TUBING
8-2	2	12" x 17" x 10 Ga. HR. SHEET STEEL
9-2	2	3 1/2" x 3 1/2" x 1/4" ANGLE x 72" LONG
10-2	4	1/4" x 1 1/2" x 12" LONG H.R. F.B.



ITEM 1-2

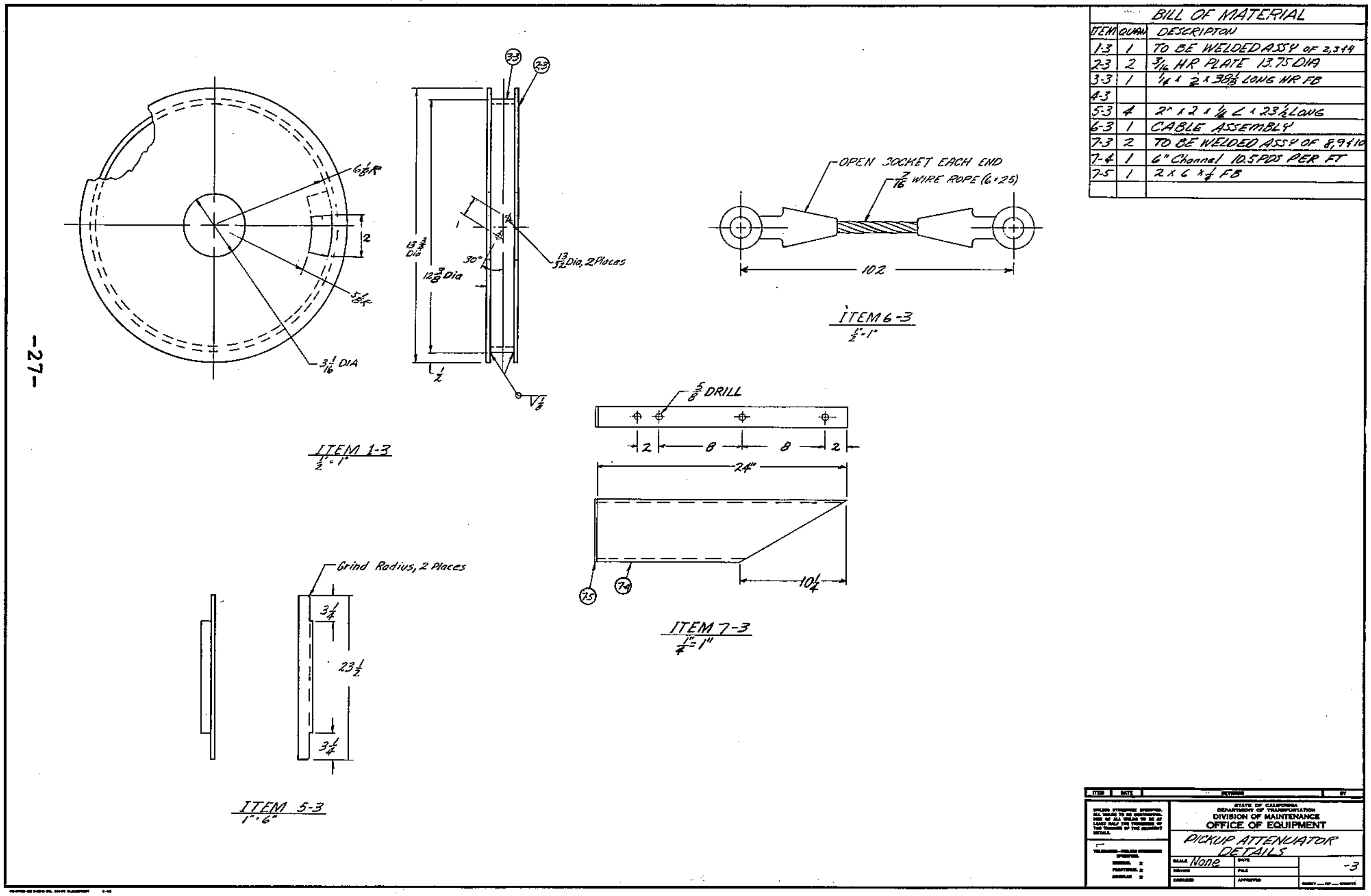
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF MAINTENANCE
OFFICE OF EQUIPMENT

PICKUP ATTENUATO DETAILS

SCALE NONE

-2

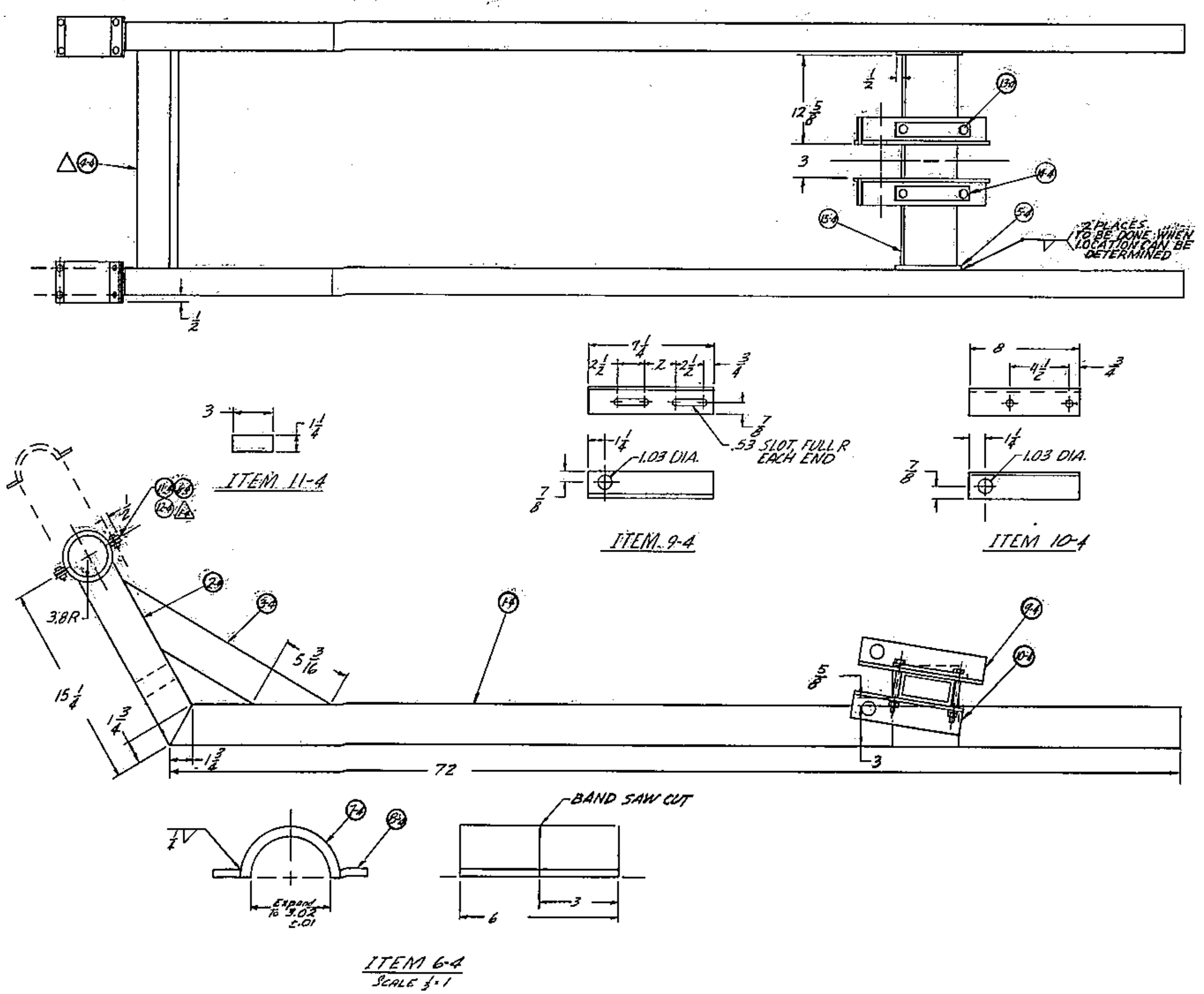
FIGURE 9



BILL OF MATERIAL

ITEM	QUAN	DESCRIPTION
1-3	1	TO BE WELDED ASSY OF 2,3+4
2-3	2	3/16 HR PLATE 13.75 DIA
3-3	1	1/4 × 2 × 38 3/8 LONG HR FB
4-3		
5-3	4	2" × 2 × 1/4 ∠ × 23 1/2 LONG
6-3	1	CABLE ASSEMBLY
7-3	2	TO BE WELDED ASSY OF 8,9+10
7-4	1	6" Channel 10.5 PDS PER FT
7-5	1	2 × 6 × 1/4 FB

FIGURE 10



BILL OF MATERIAL

Item	Quan.	DESCRIPTION
1-4	2	2 x 3 x 3/16 Wall 72 Long Rect. Mech. Tubing
2-4	2	" " " " 15 " " " "
3-4	2	" " " " 18 " " " "
4-4	1	" " " " 28 3/4 " " " "
5-4	2	5 x 6 x 1/4 HR Steel Plate
6-4	2	Item 6-4 Will Consist of 7-4 & 8-4
7-4	1	3 3/4 O.D. x 3 I.D. Round Mech. Tubing
8-4	2	1 1/2 x 6 HR Steel Flat Bar
9-4	2	2 x 2 x 1/4 x 9 1/4 HR Steel Angle
10-4	2	" " " 8 " " "
11-4	4	3 x 1 1/4 x 22 Gauge (Shim) Sheet Steel
12-4	8	7/16 x 1 1/4 NC Grade 5 Bolt, Nut & Lock Wash.
13-4	4	1/2 x 3 1/2 NF " " " " " "
14-4	2	1 x 1/4 x 6 HR Flat Bar
15-4	1	2 x 4 x 1/4 Wall x 28 1/4 Rect. Mech. Tubing
16-4		

△ CLAMP 2 HALVES OF ITEM 6-4 TOGETHER WITH ITEM 11-4 INBETWEEN AND DRILL 7/16 AND INSTALL ITEM 12.

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PICKUP ATTENUATOR DETAILS

SCALE: None

-4

FIGURE 11

5.1.4 Test Vehicles TMA

Following is a list of the passenger cars used for the truck mounted attenuator tests:

Test No.	Description	Total Weight (Lbs.)	Steel Plate Ballast Weight (Lbs.)
371*	1971 Matador 4dr	4315	717
381	1970 Dodge Coronet 4dr	4260	717
382	1970 Matador 4dr	4220	717
383	1974 Toyota Corola 2dr	2085	Ø
384	1976 Toyota Corola 2dr	2080	Ø
385	1972 Ford Pinto 2dr	2180	Ø
386	1972 Matador 4dr	4230	717
387	1972 Matador 4dr	4190	717
388	1972 Matador 4dr	4185	717
389	1970 Plymouth 4dr	4270	717

* Previous research "Vehicle Impact Tests of a Truck Mounted Attenuator Containing Vermiculite Concrete Cells" baseline test, no TMA.

The total weight of the cars includes the weight of the steel plate ballast and on-board instrumentation (about 160 lbs.), but not the 165 lb. dummy. The gas tanks were filled with water for Tests 381, 382 and 386 - 389.

The steel plate ballast was added in some test vehicles to achieve vehicle weights in the range specified in TRC 191.(5) The steel plates were bolted securely to the floorboards and distributed front and back so the weight distribution on the front and rear wheels would not be changed markedly. The steel plates were slightly below the vertical center of gravity height of the cars.

All of the cars, except the Toyotas, were retired State vehicles. They were all in good running condition and free of body damage or missing structural parts.

Although the State vehicles were older than the six year maximum age as recommended in Reference 5, the researchers believed the use of newer vehicles would not have changed the test results in any significant way. All of the cars had rear wheel drive and longitudinal engine mounting.

All vehicles were self-propelled. Steering control was achieved with a straight anchored guidance cable running through a bracket attached to the right front wheel. No constraints were placed on the steering wheel. A short distance before the point of impact, the vehicle ignition was turned off, and the car was released from the guidance cable. A speed control device on the car maintained the desired impact speed once it was attained.

Details of the car equipment are contained in Appendix A.

The same truck was used in all tests.

Description	Total Weight (Lbs.)
1965 Ford 25000 GVW	11,000 lbs.

The truck was a retired Caltrans vehicle, in running condition, free of body damage or missing structural parts, and unmodified for the tests, except for TMA mounting hardware.

In all tests the truck was parked in second gear with the spring emergency brakes engaged (truck was equipped with air brakes).

Two lightweight steel tube frames with targeting were cantilevered off the top of the dump body of the truck. They permitted smaller more detailed fields of view in the data cameras without sacrificing the means to plot the truck displacement and velocity.

5.1.5 Test Vehicles (Pickup Attenuator Tests)

Following is a list of the passenger cars used in the Pickup Mounted Attenuator Tests:

Test No.	Description	Total Weight (Lbs.)	Steel Plate Ballast Weight (Lbs.)
391	1972 Matador 4dr	4290	717
392	1972 Matador 4dr	4310	717
393	1978 Honda Civic 2dr	1820	Ø

See 5.1.4 for description of passenger car ballast.

Following are pickups used in the pickup attenuator tests.

Test No.	Description	Total Weight (Lbs.)
391*	1970 Chevrolet 3/4-ton	4415
392	1968 Dodge 3/4-ton	5000
393	1968 Dodge 3/4-ton	5000

* Baseline test no pickup attenuator

The total weight of the cars includes the weight of the steel plate ballast and on-board instrumentation (about 160 lbs.), but not the 165 lb. dummy. The gas tanks were filled with water for Tests 391-393. The total weight of the pickups in tests 392-393 includes the weight of the PMA.

All of the cars, except the Honda, were retired State vehicles. They were all in good running condition and free of body damage or missing structural parts.

Although the State vehicles were more than the six year maximum age as recommended in Reference 6, the researchers believed the use of newer vehicles would not have changed the test results in any significant way. All of the cars had rear wheel drive and longitudinal engine mounting.

All vehicles were self-propelled. Steering control was achieved with a straight anchored guidance cable running through a bracket attached to the right front wheel. No constraints were placed on the steering wheel. A short distance before the point of impact, the vehicle ignition was turned off, and the car was released from the guidance cable. A speed control device on the car maintained the desired impact speed once it was attained.

5.1.6 Data Acquisition Systems

Several high speed movie cameras were used to record the impact events. A normal speed movie camera, a video camera, and a colored slide camera were used also to picture the impact and the conditions of the test vehicles and TMAs before and after the impact. In addition black and white still photography was used to cover pre- and post-impact test conditions.

Accelerometers were mounted on the floorboard of the car and on the floorboard in the truck cab. Acceleration data were collected to judge impact severity and the chance of passenger injuries or fatalities.

In the TMA tests, an anthropomorphic dummy with accelerometers mounted in its head cavity, was placed in the driver's seat of the passenger car to obtain motion and acceleration data. The dummy, Willie Makit, a Part 572 dummy built to conform to Federal Motor Vehicle Safety Standards by the Sierra Engineering Company, is a 50th percentile American male weighing 165 lbs. The dummy was restrained with a standard lap and shoulder belt for all TMA tests.

In the PMA tests, the Part 572 was placed in the drivers seat of the pickup and restrained with a lap belt. For these tests an older model 50th percentile dummy, Sierra Stan, was placed in the drivers seat of the car. It was restrained with a lap and shoulder belts in tests 391 - 392, but had no restraints in test 393. A sliding weight device was attached to the right side of the car. Upon impact the weight, fitted with ball bearings, would slide two feet forward on a smooth rod. This could be used to calculate the rattlespace time, if a malfunction occured with electronic instrumentation.

Appendices B and C contain a detailed description of the photographic and electronic equipment, camera and accelerometer layout, data collection and reduction techniques, and accelerometer records.

5.1.7 Test Parameters

Following are the parameters for the TMA crash tests:

TEST CARS

Test No.	Car Weight (Lbs.)	Speed (MPH)	Angle (Degrees)
371	4315	45	0° Head-On ℄
381	4260	45.8	0° Head-On ℄
382	4220	43.9	0° Head-On ℄
383	2085	44.7	0° Head-On ℄
384	2080	43.2	0° Head-On ℄
385	2180	44.4	0° Head-On ℄
386	4230	45.1	0° Head-On ℄
387	4190	45.5	0° Head-On ℄
388	4185	46.4	0° Head-On ℄
389	4270	44.8	10°, 1 ft. Offset

TEST TRUCKS

Test No.	Truck Wt.(Lbs.) W/O TMA	TMA Wt. (Lbs.)	Braking
371	11,600	None	All wheels braked
381-385	11,000	970	Rear Wheels braked
386-389	11,000	700	Transmission 2nd Gear

Following are the parameters for the PMA crash test:

Test No.	Car Weight (Lbs)	Speed (MPH)	Angle (Degrees)
391	4290	43.9	0° Head-On℄
392	4310	45.3	0° Head-On℄
393	1820	44.8	0° Head-On℄

TEST PICKUPS

Test No	Pickup Weight (Lbs.) W/O PMA	PMA Weight (Lbs.)	Braking
391	4415	None	Emergency Brake
392	4140	860	Emergency Brake
393	4140	860	Emergency Brake

5.2 Truck Mounted Attenuator Test Results

Accelerometer records from the cars, trucks, and head of the dummy are contained in Appendix C. A film report has been assembled which shows all TMA tests.

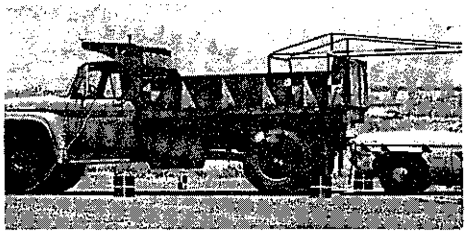
5.2.1 Test 371: Car-4315 lbs/45 mph/0° Head-on
Truck-11,600 lbs/all wheels braked/No TMA

As stated earlier, Test 371 was done for previous research and was used for a baseline test for this research.

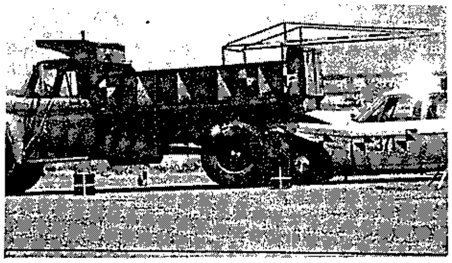
The summary of test data and photos of the vehicles before and after impact are shown in Figures 12 - 14.

Impact Description - 371: The car struck the truck at the intended speed and angle. The car was 9 inches off center to the left of the truck center line. The front of the car was severly crushed and compressed against the rear of the truck before the truck began to move. Initially, after impact, the truck bed was

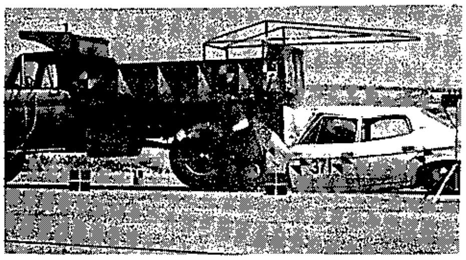
FIGURE 12 - DATA SUMMARY SHEET - TEST 371



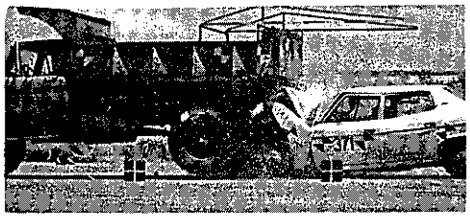
Impact +0.0 Sec.



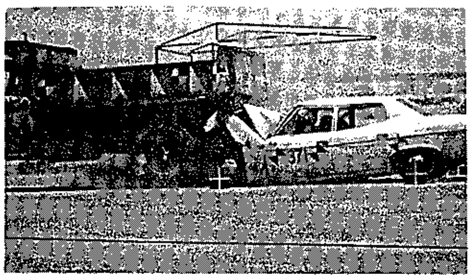
Impact +0.04 Sec.



Impact +0.14 Sec.



Impact +0.31 Sec.



Impact +1.83 Sec.

Test Date	June 21, 1979

Truck Mounted Attenuator Data

Type	Not Used This Test
Size	Not Used This Test
Weight	Not Used This Test

Truck Data

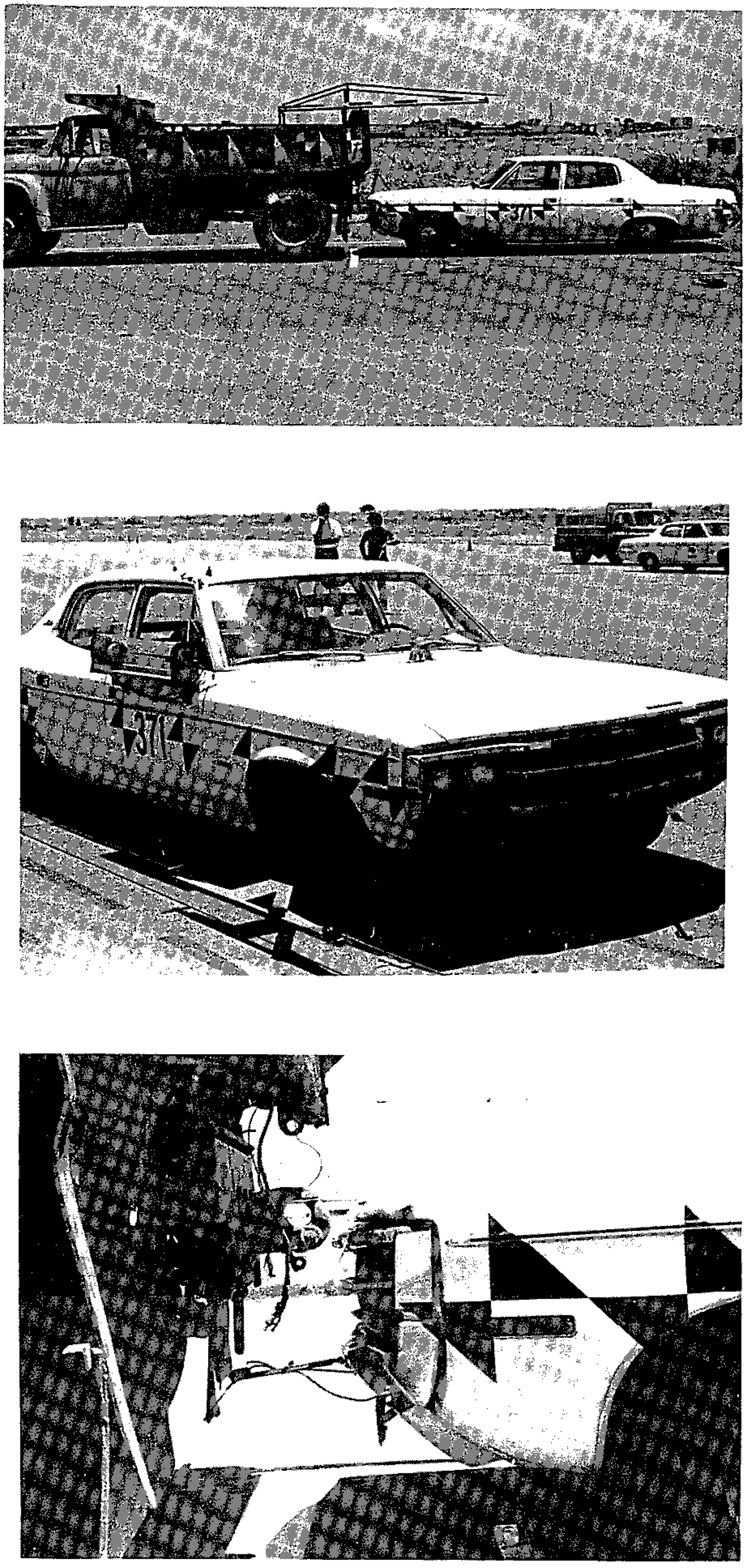
Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Air Brakes, All Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,600 lbs.

Car Data

Model	1971 AMC Matador
Impact Velocity	45 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	4315 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-21.5 g's
Car, Vertical	No Data
Truck Longitudinal	5.0 g's
Dummy Head, Result, Car, (No Vert.)	-39.2 g's
Head Injury Criterion	No Data
Occupant Impact Velocity (Film Data)	46 fps
Truck Roll Ahead Distance	10.3 ft.
Maximum Pitch, Car (Rear End)	-8.0°
Maximum Rise, Truck Dump Body Rear	10.0 in.
TAD/VDI Index, Car	FD-7/12FDEW6



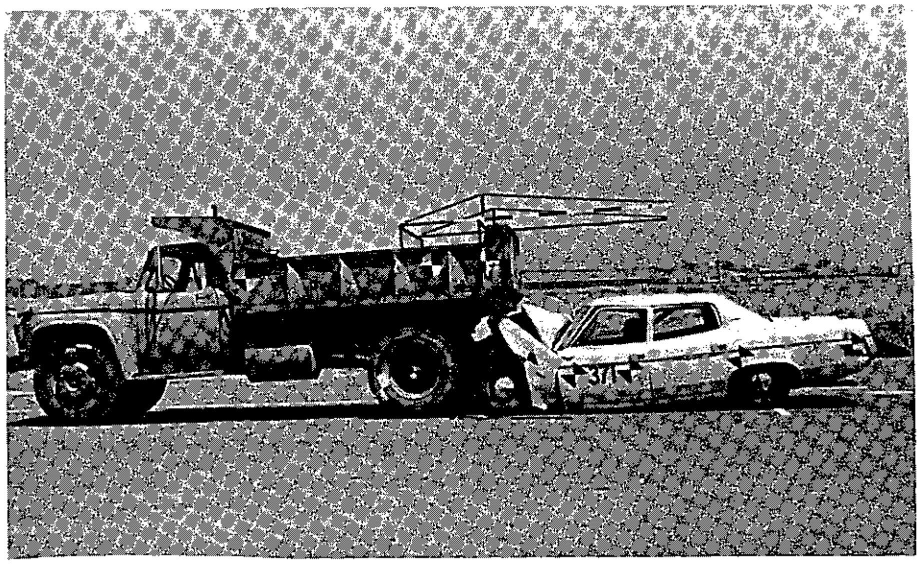
FIGURF 13

Test 371

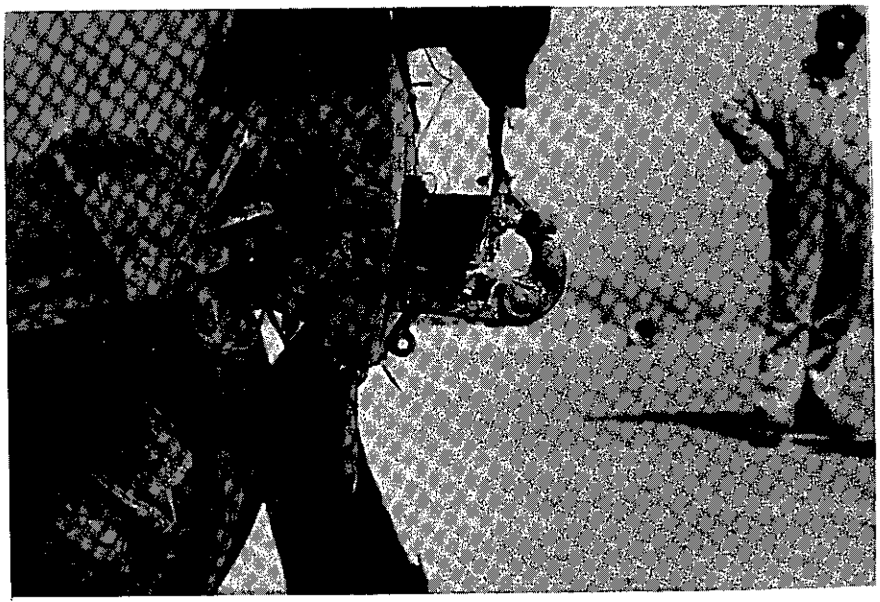
Test Vehicles Before Impact

FIGURE 14

Test 371



Test Vehicles After Impact



forced upward and the rear wheels were lifted a few inches off the ground as the truck moved forward. During this time, the rear wheels did not turn until they made contact with the ground again. After the maximum compression of the front end of the car occurred, the car appeared to re-extend slightly due to the storage of elastic energy. However, the car was hooked onto the truck and traveled with it to a stop. The truck moved forward a total of 10-feet 4-inches. There was minimal yawing and pitching of the car during impact.

The maximum 50 millisecond average value of longitudinal acceleration for the passenger compartment of the car was -21.5 g's. The comparable value of longitudinal acceleration in the cab of the truck was 5.0 g's.

Car Damage - 371: Damage to the car was quite extensive. The front end was severely crushed an average of approximately 26.5 inches at a height of 24-inches above ground. The hood was crushed back a maximum of 37-inches. The windshield was broken by the hood. The radiator was crushed back to the fan. All four doors were jammed. The roof over the doorposts was crimped indicating buckling in the car body as a whole. The engine moved back slightly, and the tires were restricted against movement. The car could not have been driven or rolled away from the test site. The dashboard and steering column were pushed a short distance into the passenger compartment, otherwise there was no intrusion of vehicle parts. Buckling in the floorboard damaged one of the accelerometers. The steel ballast plates remained attached.

Truck Damage - 371: Damage to the truck was relatively light. The rear crossmember, differential cover, and rear springs were bent. A rear brake actuator was torn loose from its location near the inside face of the rear tire, and the brake lines were ripped loose. Although the truck could be driven, there must have been some damage to the drive train because it did not operate smoothly.

5.2.2 Test 381: Car - 4260 lbs/45.8 mph 0° Head-On
Truck - 11,900 lbs/rear wheels braked with TMA

The summary of the test data and photo of venicles before and after impacts are shown in Figures 15 - 17.

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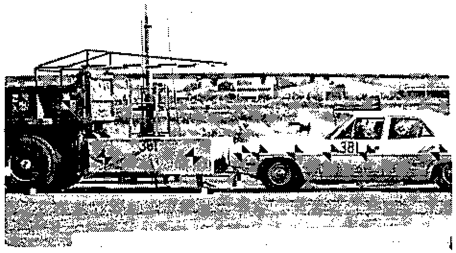
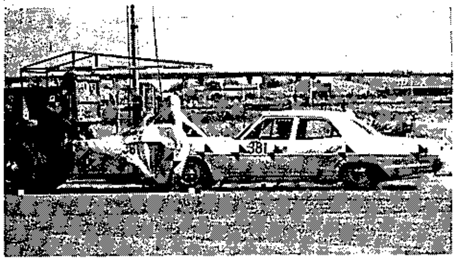
[illegible] PRODUCT

FIGURE 15 - DATA SUMMARY SHEET - TEST 381



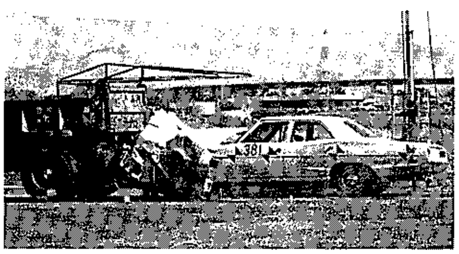
Impact -0.01 Sec.



Impact +0.06 Sec.

Impact +0.20 Sec.

Impact +0.48 Sec.



Impact +1.20 Sec.

Test Date October 23, 1980

Truck Mounted Attenuator Data

Type	Hexcel Aluminum Honeycomb
Size	7' Long x 7'-8"Wide x 2'High
Weight	280 lbs., TMA
	690 Lbs., Mounting Hardware

Truck Data

Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,000 lbs.

Car Data

Model	1970 Dodge Coronet
Impact Velocity	45.8 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	4260 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

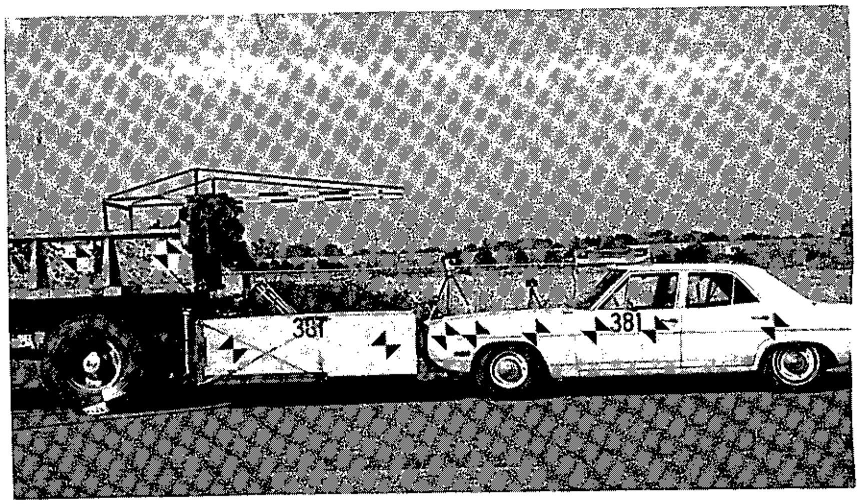
Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-11.4 g's
Car, Vertical	-4.6 g's
Truck Longitudinal	3.6 g's
Dummy Head, Resultant, Car	-17.4 g's
Head Injury Criterion	102
Occupant Impact Velocity, Longitudinal	31.6 fps
Truck Roll Ahead Distance	29'-8"
Maximum Pitch, Car (Rear End)	-7°
Maximum Rise, Truck Dump Body Rear	3.9 in.
TAD/VDI Index, Car	FD-4/12FDEW5

MANAGEMENT

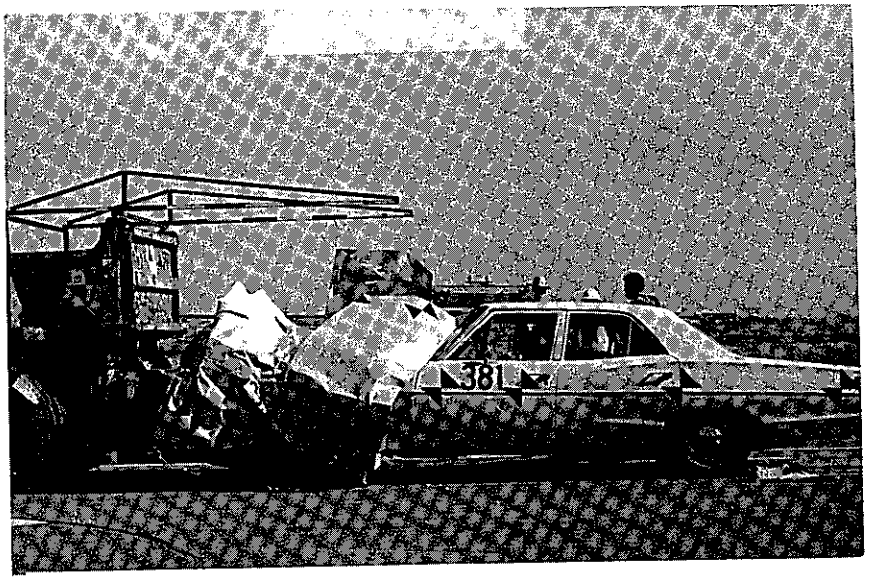
A HAMM [illegible]

FIGURE 16

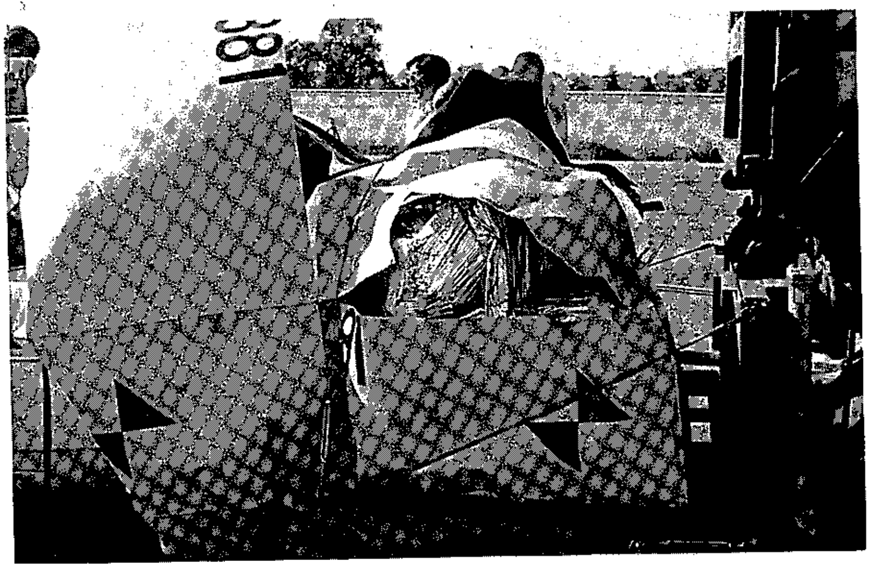
Test 381



Test Vehicles and TMA Before Impact



Final Positions of Test Vehicles

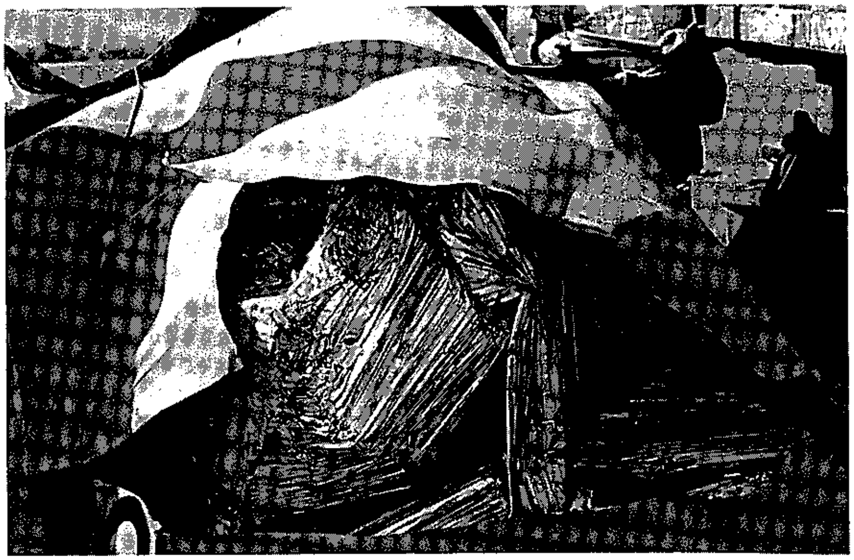


TMA Crushed About Six Feet No Damage to Truck or TMA Hardware

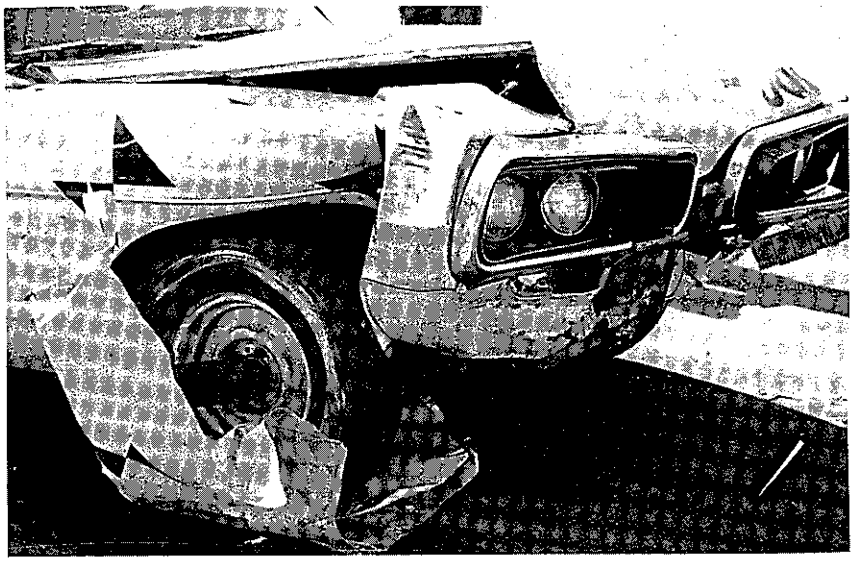
FIGURE 17

Test 381

Three-quarter Inch Plywood Performed as a Diaphragm During Impact



Premature Column Failure of TMA Cells



Test Car Damage

Impact Description - 381: The car struck the TMA at the intended speed and angle on center line. There was little movement of the truck, while the car crushed the TMA. The car penetrated the TMA 6-feet. The truck rolled ahead 29-feet 8-inches. The truck transmission popped out of second gear and allowed more roll ahead than anticipated.

The lower covering of the TMA collapsed to the ground providing a ramp for the car to roll up on the undercarriage of the TMA. This caused a vertical component of force causing premature failure of the TMA honeycomb cells.

Car Damage - 381: Damage to the car was severe but less than test 371. The front end was uniformly crushed back 10 inches. All four doors were opened easily. The radiator was moved back to the fan. The engine position was not changed. All damage was confined to the front fenders and hood area. There was no intrusion or damage inside the car. The windshield was intact. The car required towing from the impact location.

Truck Damage - 381: There was no truck damage.

TMA Damage - 381: Almost all of the TMA honeycomb cells were damaged in the test. The car (72 inches) wide being narrower than the TMA (92 inches) wide, penetrated the center of the TMA. Total penetration was 78 inches of the 84 inch length of the TMA. The horizontal orientation and the length (See Figure 3) of the cell blocks caused a premature column buckling of the cells in the second to last section of the TMA. This resulted in the cells not providing their full compressive potential. Although the acceleration levels were acceptable, it was felt the vertical angle at which the car rode up used additional energy, resulting in the low accelerations. This condition could result in a lighter car rolling over. By orientating cells vertically and modifying the outer covering so it would not form a ramp for the car to ride up, it would eliminate the chance of a rollover.

5.2.3 Test 382

The purpose of Test 382 was to evaluate changes made in the TMA design.

Car - 4220 lbs/43.9 mph 0° Head-On
Truck 11000 lbs/rear wheels braked
TMA - 970 lbs.

The summary of the test data and photos of vehicles before and after impacts are shown in Figures 18 - 20.

Changes to TMA Design: The TMA honeycomb cells were orientated vertically and all sections were reduced to about 9 inches in length, except for the last section which remained at 18 inches. (See Figure 1) The lower skin (covering) was attached so that it would collapse on impact and not cause a ramp for the car to ride up.

Impact Description - 382: The car struck the TMA at the intended speed and angle on center line. There was little movement of the truck while the car crushed the TMA. The car penetrated the TMA 62 inches. The car and truck rolled ahead 16-feet 8-inches after impact. The horizontal angle (pitch) of the car during impact was minimal. The car moved a total of 95-inches plus 12-inches of crush to the front of the car during impact. The car remained on center line with the truck. The impact area was free of any debris.

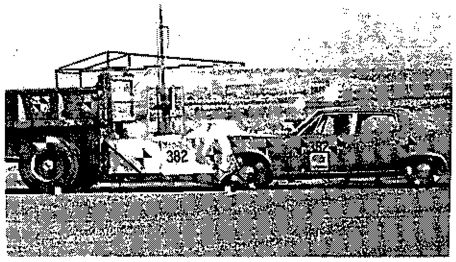
Car Damage - 382: Damage to the car was severe and comparable to Test 381. All major damage was confined to the front fenders and hood areas. The radiator was moved back to the engine, the engine position was unchanged. The front doors were jammed, but easily opened. The windshield was unbroken. The door posts were undamaged. In the interior, the dummy struck its knee on the underside of the dash and caused a dent. The steering wheel was intact. The floorboard over the transmission buckled. The tires were intact. The car required towing from the impact location.

Truck Damage - 382: There was no truck damage.

TMA Damage - 382: Almost all of the TMA honeycomb cells were damaged in the test. The car penetrated within the outer sides of the TMA. Unlike Test 381 the honeycomb cells absorbed more of the impact energy. The changes made in the TMA design resulted in the

FIGURE 18 - DATA SUMMARY SHEET - TEST 382

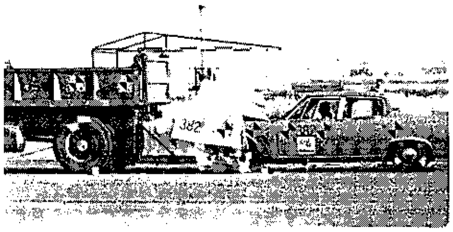
Test Date	December 18, 1980



Impact +0.03 Sec.

Truck Mounted Attenuator Data

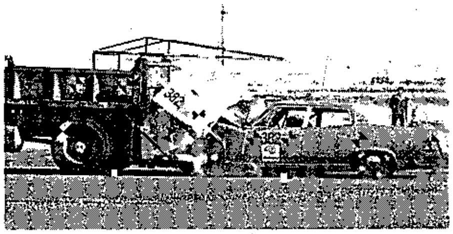
Type	Hexcel Aluminum Honeycomb
Size	7'Long x 7'-8"Wide x 2'High
Weight	280 lbs., TMA
	690 Lbs., Mounting Hardware



Impact +0.09 Sec.

Truck Data

Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,000 lbs.



Impact +0.22 Sec.

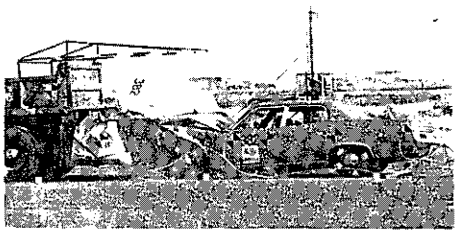
Car Data

Model	1972 AMC Matador
Impact Velocity	43.9 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	4220 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact +0.72 Sec.

Impact Data

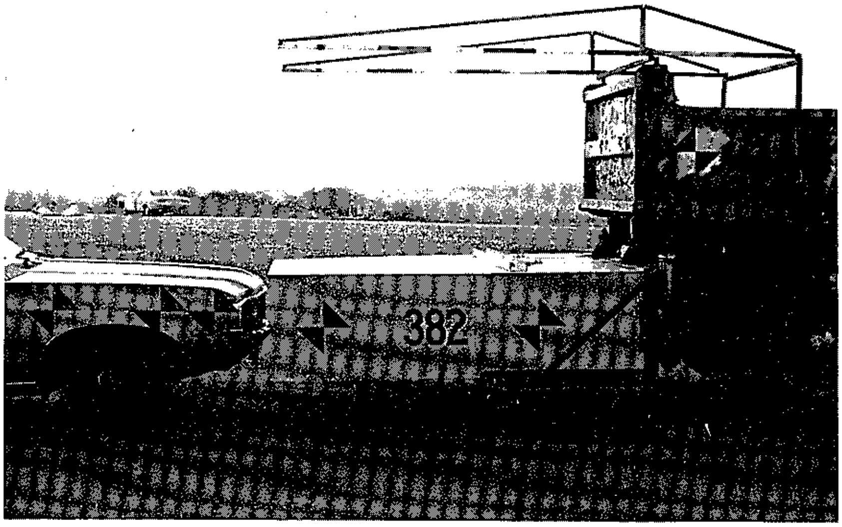
Maximum 50ms. Avg. Acceleration,	Accelerometer Data
Car, Longitudinal Not Calculated	-12.1 g's
Car, Vertical	4.6 g's
Truck Longitudinal	3.8 g's
Dummy Head, Resultant, Car	-16.0 g's
Head Injury Criterion	85
Occupant Impact Velocity, Longitudinal	34.3 fps
Truck Roll Ahead Distance	16'-8"
Maximum Pitch, Car (Rear End)	+3.50
Maximum Rise, Truck Dump Body Rear	4.4 in.
TAD/VDI Index, Car	FD-5/12FDEW5



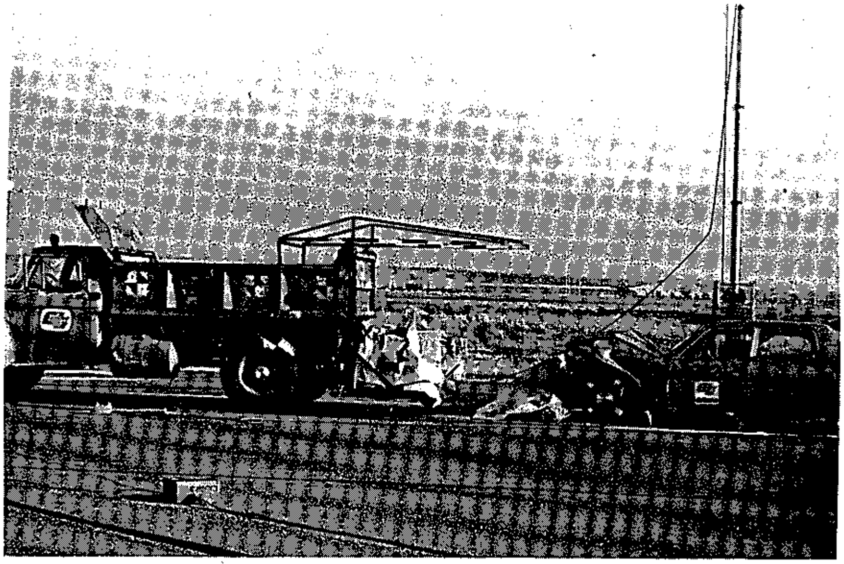
Impact +1.18 Sec.

FIGURE 19

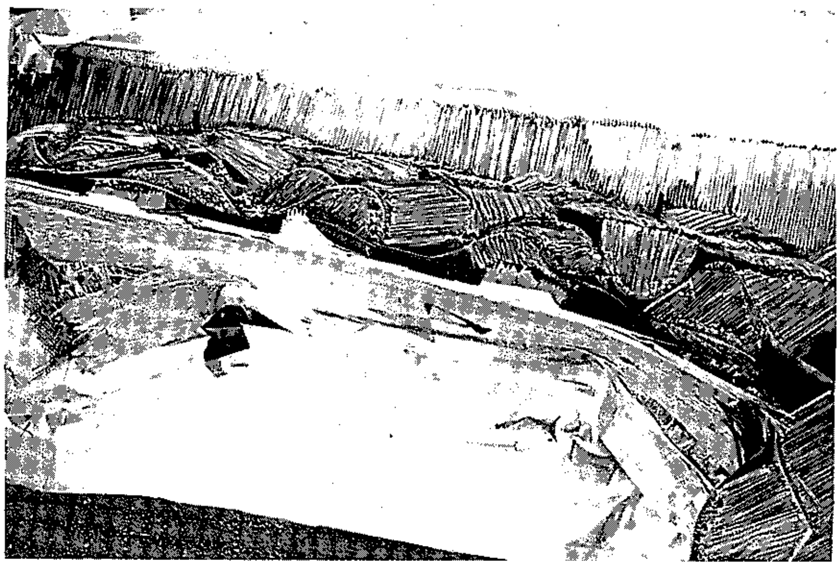
Test 382



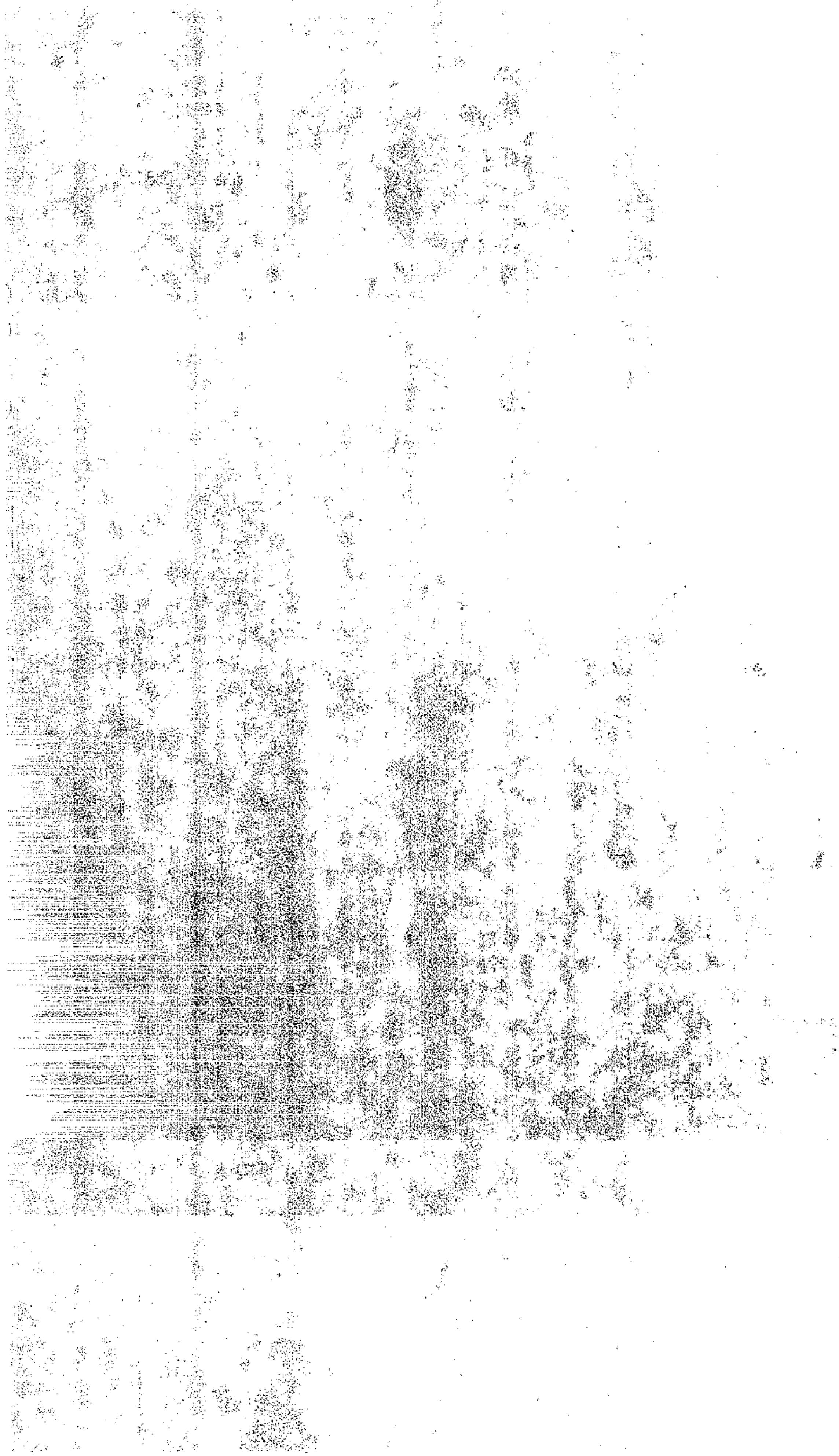
Test Vehicles and TMA Before Impact



Final Positions of Test Vehicles



TMA Crushed 62-Inches



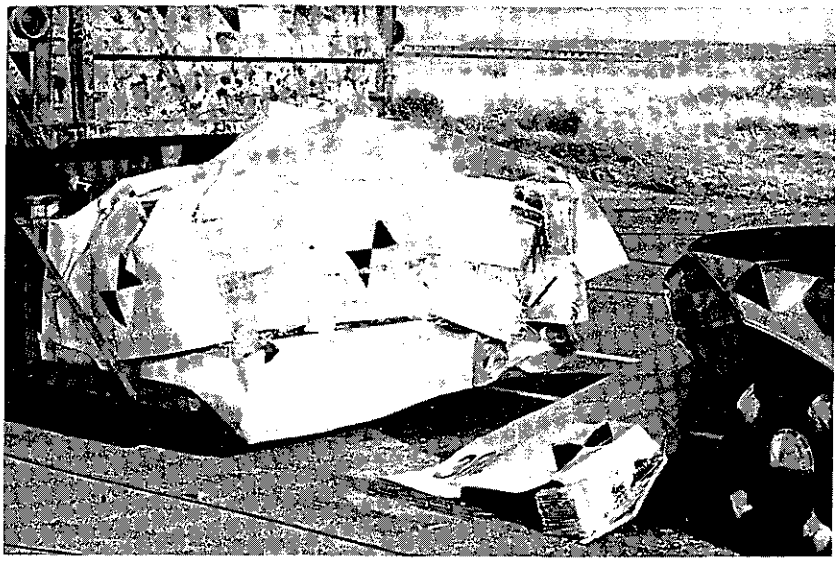
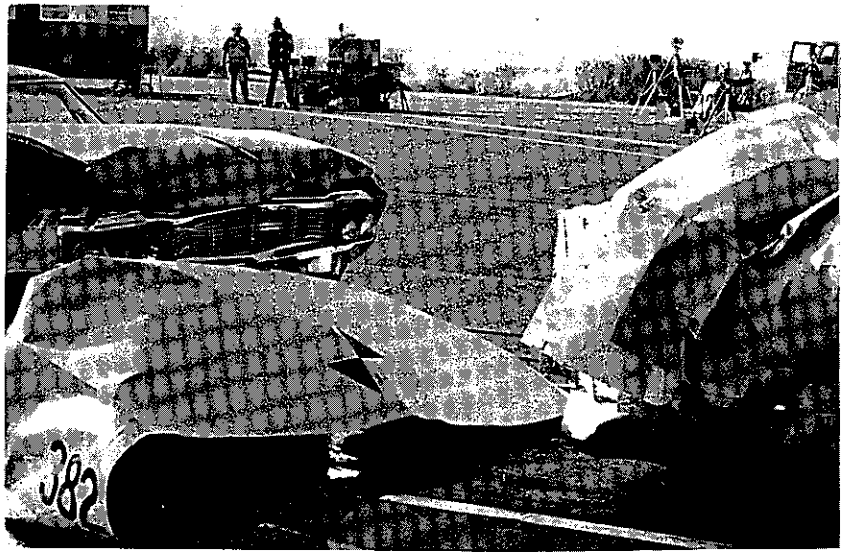


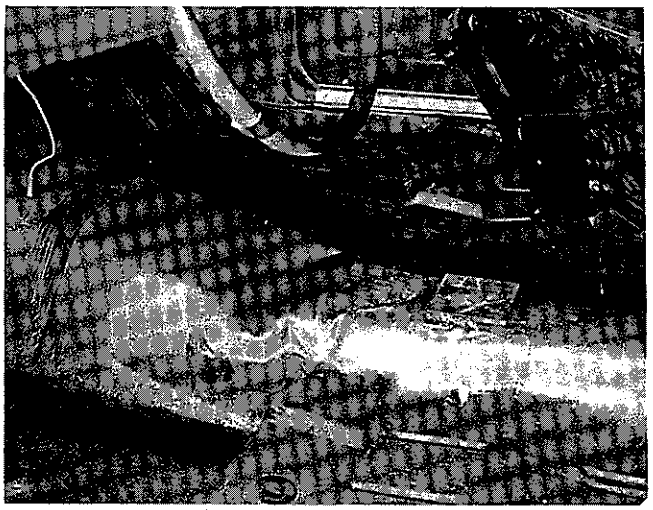
FIGURE 20

Test 382

Three-quarter Inch
Plywood Diaphragm



Car Front Crush was
12-Inches



Car Floorboard
Buckled

car being retained with minimal pitching and the shorter honeycomb cells orientated vertically not buckling as in Test 381. The undercarriage was partially collasped.

5.2.4 Test 383

The purpose of Test 383 was to evaluate the TMA design being impacted by a lightweight car.

Car - 2085 lbs/44.7 mph 0° Head-On
Truck - 11000 lbs/rear wheels braked
TMA - 970 lbs.

The summary of the test data and photos of vehicles before and after impacts are shown in Figures 21 - 23.

Changes to TMA Design - 383

The TMA was the same design as Test 382.

Impact Description - 383

The car struck the TMA at the intended speed and angle on center line. There was little movement of the truck while the car crushed the TMA. The car penetrated the TMA 36-inches. The front of the car was crushed in 12-inches. The car rolled ahead 10-feet 5-inches after impact. The truck rolled ahead 6-feet 5-inches. The horizontal angle (pitch) of the car during impact was minimal. The car and truck came to rest on the center line of impact. The impact area was free of debris.

Car Damage - 383

Damage to the car was severe. All damage was confined to the front fenders and hood areas. The front of the car was uniformly crushed back 12-inches. The radiator was moved back to the fan. The engine position was unchanged. The front doors were not jammed. There was no damage to the door posts. The roof over the door posts was crimped. The dummy struck its knees on the bottom of the dash causing small dents. There was no deflection of the steering wheel. The windshield was unbroken. All tires were intact. The car had to be towed from the impact area.

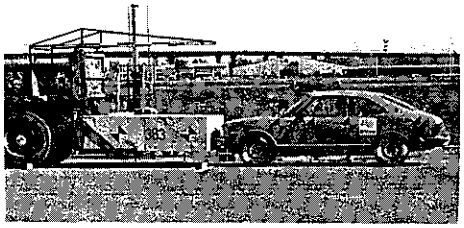
Truck Damage - 383

There was no truck damage.

MANAGEMENT

FIGURE 21 - DATA SUMMARY SHEET - TEST 383

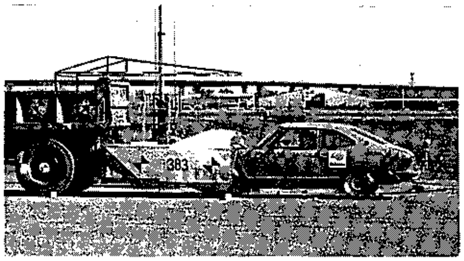
Test Date	February 18, 1981



Impact +0.0 Sec.

Truck Mounted Attenuator Data

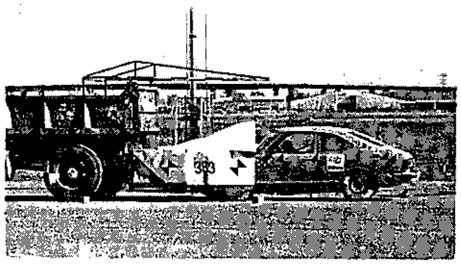
Type	Hexcel Aluminum Honeycomb
Size	7'Long x 7'-8"Wide x 2'High
Weight	280 lbs., TMA
	690 Lbs., Mounting Hardware



Tmpact +0.05 Sec.

Truck Data

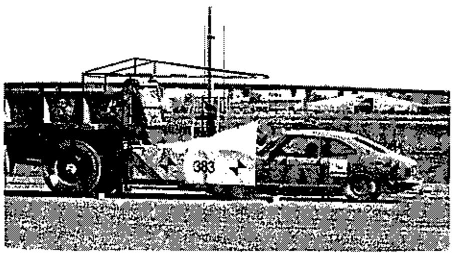
Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,000 lbs.



Impact +0.10 Sec.

Car Data

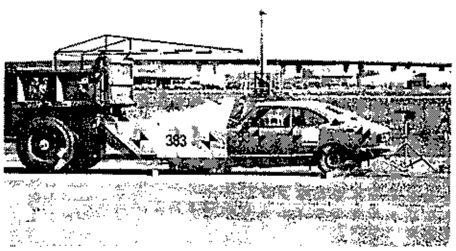
Model	1974 Toyota - Corolla
Impact Velocity	44.7 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	2085 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts



Impact +0.20 Sec.

Impact Data

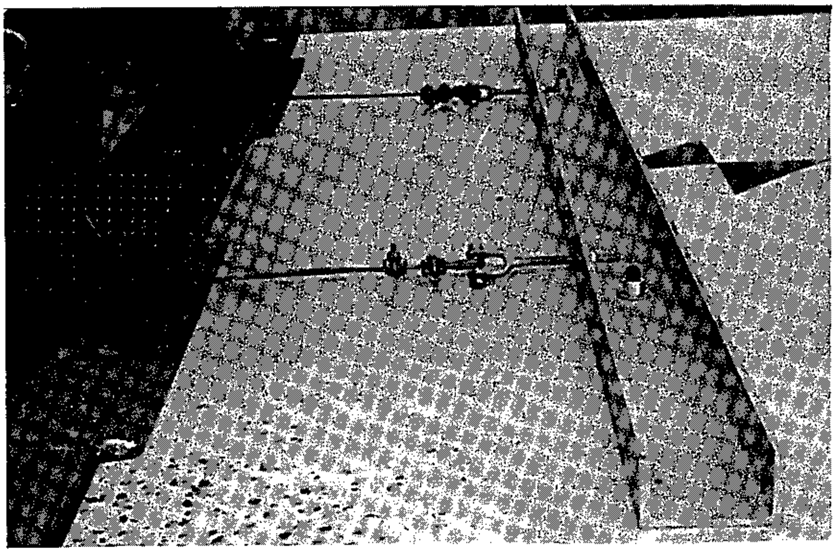
Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-15.7 g's
Car, Vertical	1.1 g's
Truck Longitudinal	3.3 g's
Dummy Head, Resultant, Car	-36.4 g's
Head Injury Criterion	427
Occupant Impact Velocity, Longitudinal	42.7 fps
Truck Roll Ahead Distance	6'-5"
Maximum Pitch, Car (Rear End)	1.0°
Maximum Rise, Truck Dump Body Rear	1.8 in.
TAD/VDI Index, Car	FD-5/12FDEW5



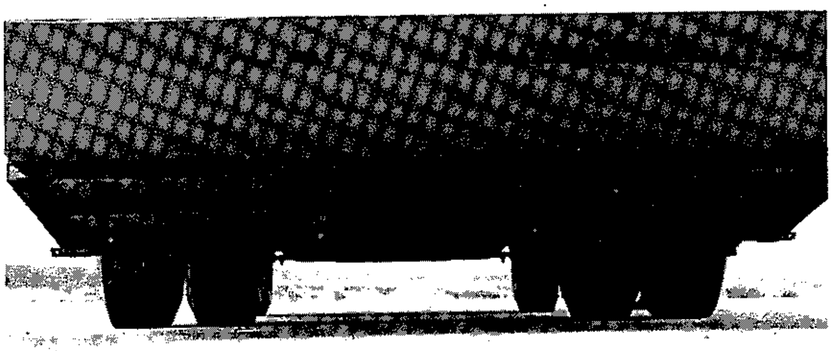
Impact +1.22 Sec.

FIGURE 22

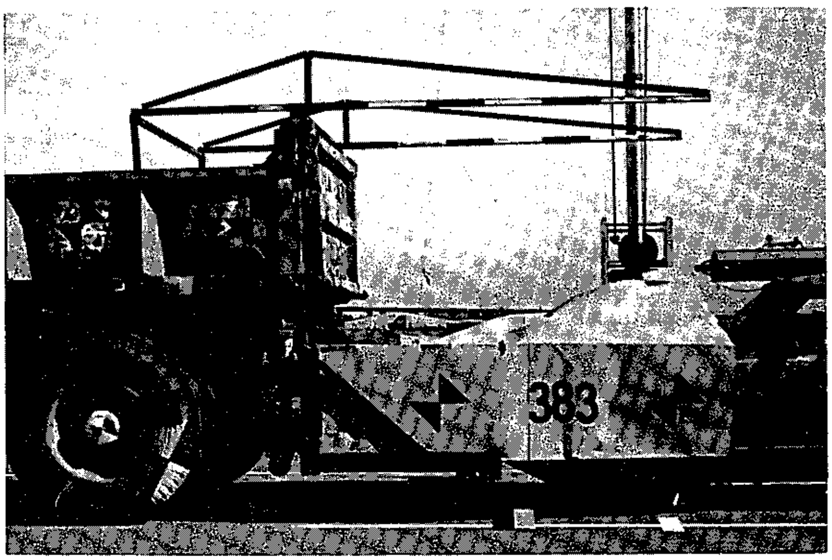
Test 383



TMA Attachment to Head Frame Tests 381 thru 385



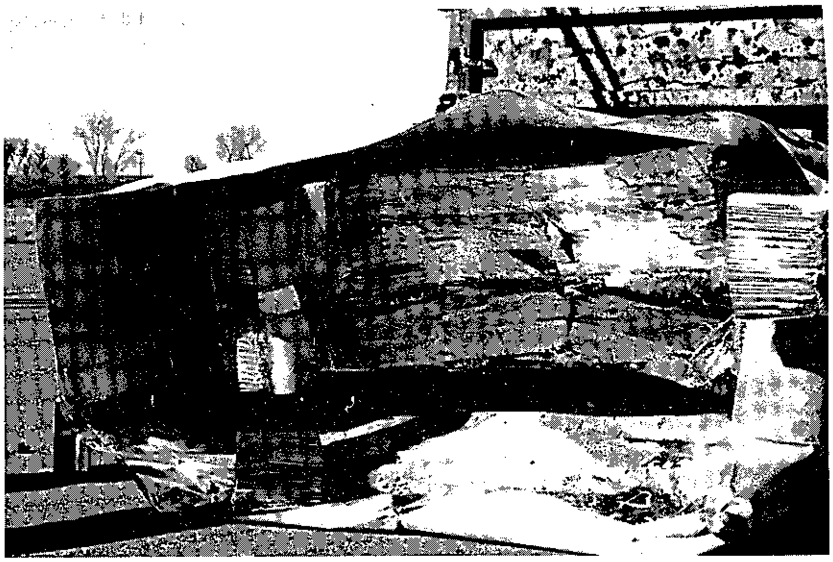
TMA Undercarriage Tests 381 thru 385



Final Positions of Test Vehicles

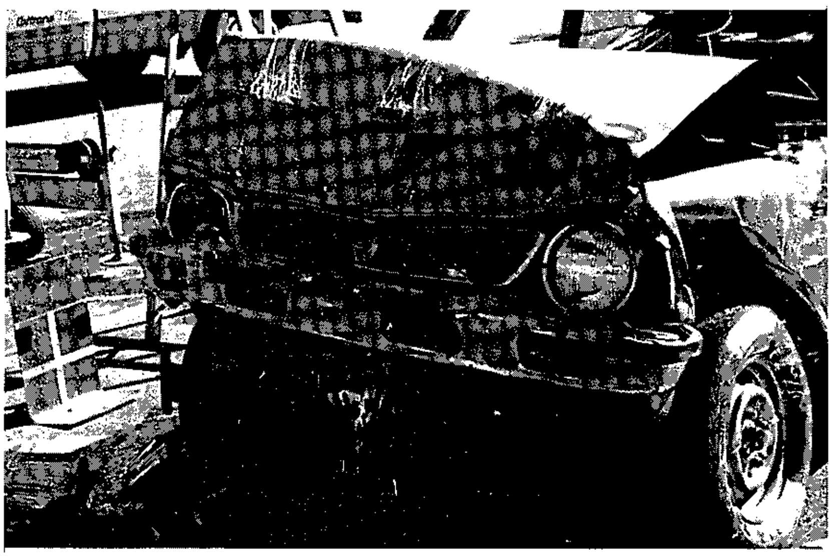
FIGURE 23

Test 383



Three-quarter Inch Plywood Diaphragm

TMA Crushed 36-Inches



Car Front Crush was 12-Inches

[illegible]

[illegible]

TMA Damage - 383
Only forty percent of the honeycomb cells were damaged during the impact. The car penetrated a 60-inch width (car width) of the 92-inch wide TMA on center line. The penetration of the car was 36-inches into the TMA. The outer covering of the TMA engulfed the car resulting in a very clean and debris free impact. The undercarriage was undamaged.

5.2.5 Test - 384
The purpose of Test 384 was to evaluate a redesigned TMA to provide improved results for a lighweight car impact test.

Car - 2080 lbs/43.2 mph 0° Head-On
Truck - 11000 lbs/rear wheels braked
TMA - 970 lbs.

The summary of the test data and photos of vehicles before and after impacts are shown in Figures 24 - 26.

Changes to TMA Design - 384: The honeycomb cell area was decreased throughout the length of the TMA to increase the length of crush and thus decrease the accelerations (g's). (See Figure 3 for cell area configurations).

Impact Description - 384: The car struck the TMA at the intended speed and angle on center line. There was little movement of the truck during impact of the TMA.

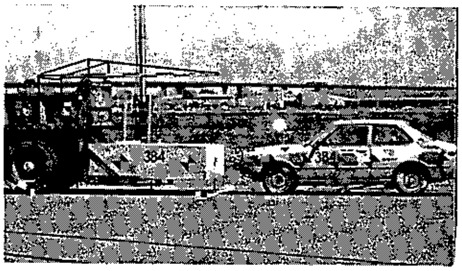
The car penetrated the TMA 52-inches. The front of the car crushed back 14-inches. The car rolled ahead 11-feet 6-inches after impact. The truck rolled ahead 6-feet 1-inch. Pitching and yawing of the car during impact was minimal. The car and truck came to rest on center line of the impact. The impact area was free of debris.

Car Damage - 384: Damage to the front of the car was severe. All front end components were crushed. The radiator was crushed back to the fan. The engine position was unchanged. Doors were not jammed and door posts were not damaged. The roof over the door post was not crimped as it was in Test 383. There was no interior damage. The windshield was intact. All tires were still inflated. The car was towed from the impact location.

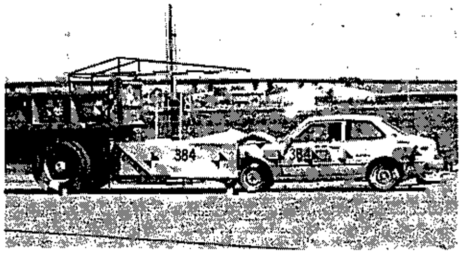
[illegible]ANAGEM[illegible] [illegible]ND[illegible]

[illegible]

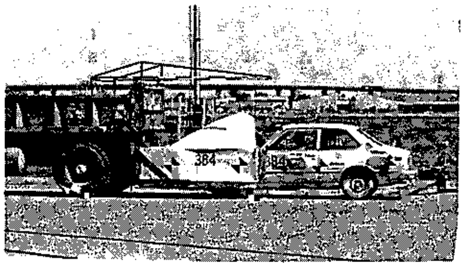
FIGURE 24 - DATA SUMMARY SHEET - TEST 384



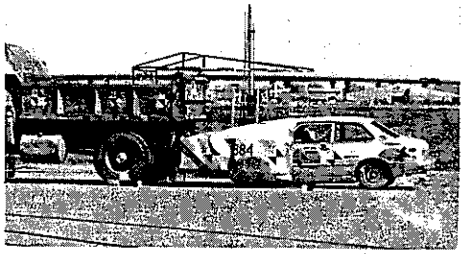
Impact -0.02 Sec.



Impact +0.04 Sec.



Impact +0.09 Sec.



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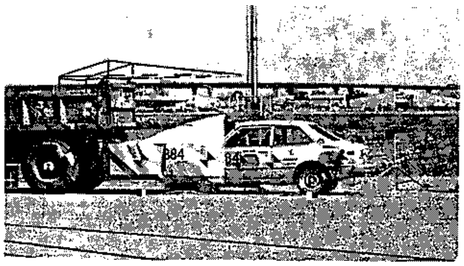


Impact +1.26 Sec.

Test Date	April 9, 1981

Truck Mounted Attenuator Data

Type	Hexcel Aluminum Honeycomb
Size	7'Long x 7'-8"Wide x 2'High
Weight	280 lbs., TMA
	690 Lbs., Mounting Hardware

Truck Data

Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,000 lbs.

Car Data

Model	1976 Toyota - Corolla
Impact Velocity	43.2 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	2080 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-16.0 g's
Car, Vertical	4.5 g's
Truck Longitudinal	2.7 g's
Dummy Head, Resultant, Car	-29.7 g's
Head Injury Criterion	250
Occupant Impact Velocity, Longitudinal	36.8 fps
Truck Roll Ahead Distance	6'-1"
Maximum Pitch, Car (Rear End)	3.0°
Maximum Rise, Truck Dump Body Rear	1.7 in.
TAD/VDI Index, Car	FD-5/12FDEW5

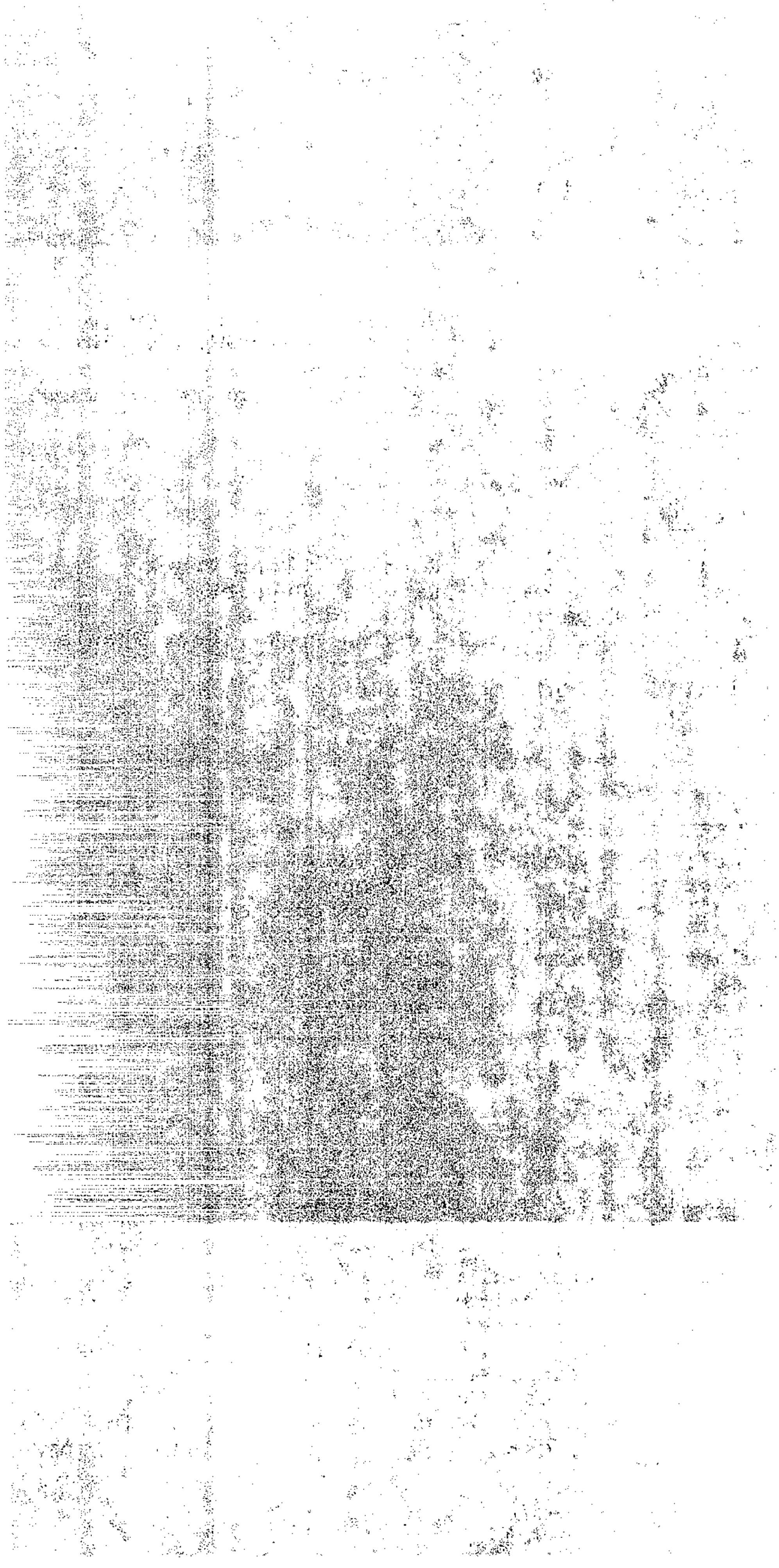
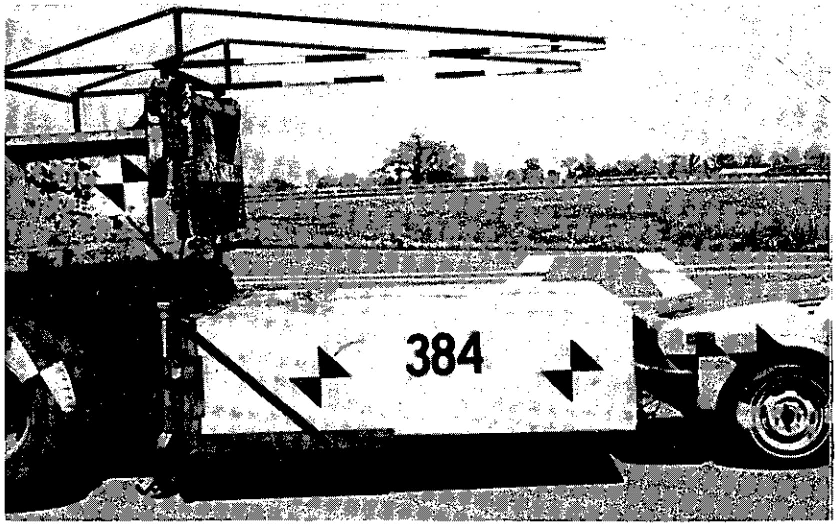
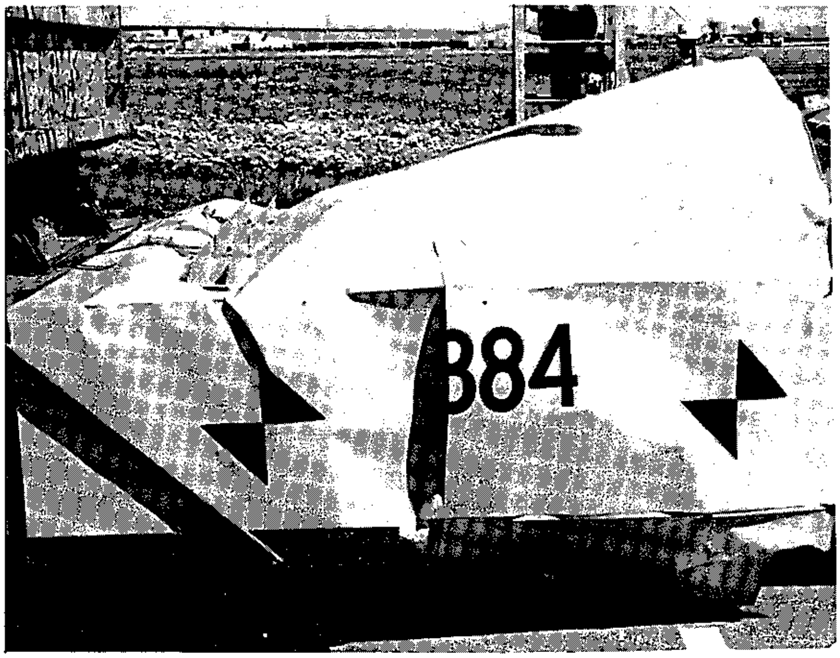


FIGURE 25

Test 384



Vehicles Before Impact



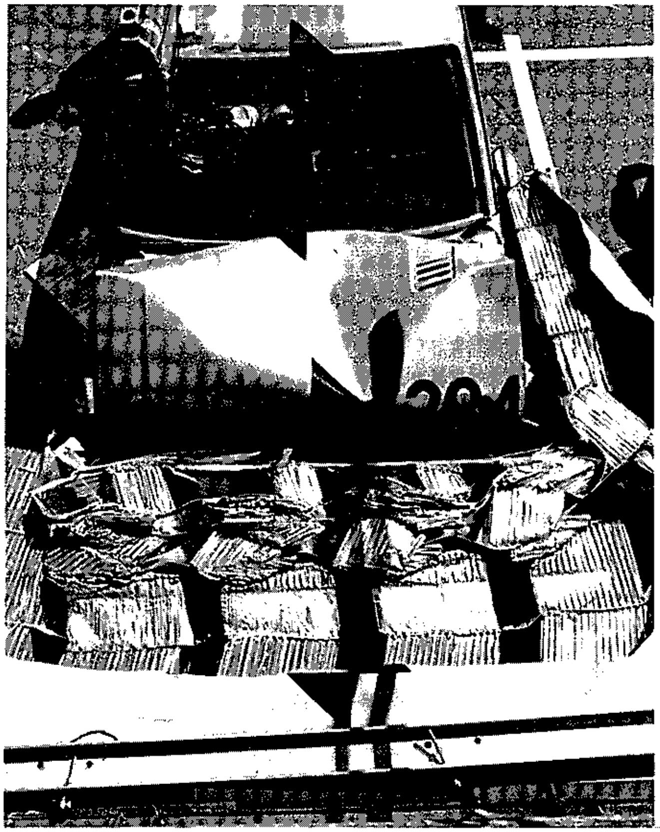
Final Positions Car Engulfed in TMA

Car Impacted on Center Line

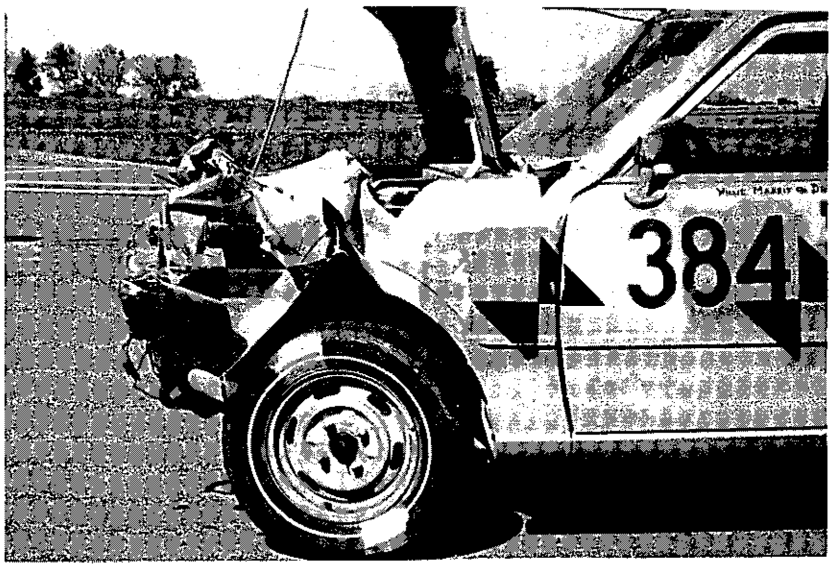
MANAGEMENT

FIGURE 26

Test 384



Car Penetrated the TMA 52-Inches



Car Crush was 14-Inches

Truck Damage - 384: There was no truck damage.

TMA Damage - 384: Sixty percent of the honeycomb cells were damaged during the impact. The car penetrated a 60-inch width (car width) of the 92-inch wide TMA on center line. The pentration of the car was 52-inches into the TMA. The outer covering engulfed the front end of the car. The undercarriage was undamaged.

5.2.6 Test - 385

The purpose of Test 385 was to evaluate changes in the TMA honeycomb cell layout and to acquire more uniform accelerations than in Test 384 during a lighweight car impact.

Car - 2180 lbs/44.4 mph 0° Head-On
Truck - 11000 lbs/rear wheels braked
TMA - 970 lbs.

The summary of the test data and photos of vehicles before and after impacts are shown in Figures 27 - 29.

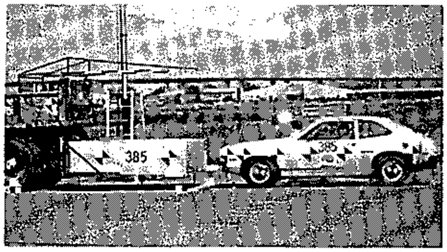
Changes to TMA Design - 385: The honeycomb cell area was increased in the first two sections to provide a more uniform crush and reduce the accelerations (g's). (See Figure 3 for cell area configurations).

Impact Description - 385: The car struck the TMA at the intended speed and angle on center line. There was little movement of the truck during the impact of the TMA. The car penetrated the TMA 52-inches. The car rolled ahead 7-feet 9-inches after impact. The truck rolled ahead 6-feet 9-inches after impact. Pitching and yawing of the car was minimal. The car and truck came to rest on center line of the impact. The impact area was free of debris.

Car Damage - 385: Damage to the front end body components was severe. The front of the car was crushed back 12-inches. The radiator was crushed back to the fan. The engine position was unchanged. Doors were not jammed and door posts were not damaged.

The roof line around the front of the door was slightly deformed. There was no interior damage. The windshield was intact. All tires were intact and inflated. The car required towing from the impact area.

FIGURE 27 - DATA SUMMARY SHEET - TEST 385



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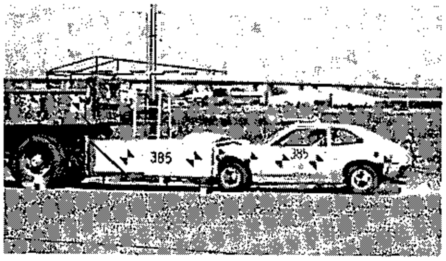
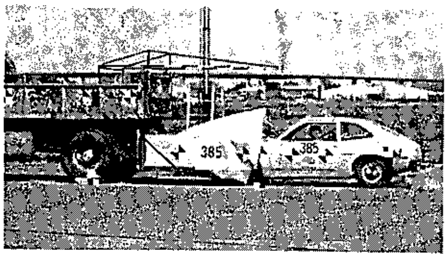
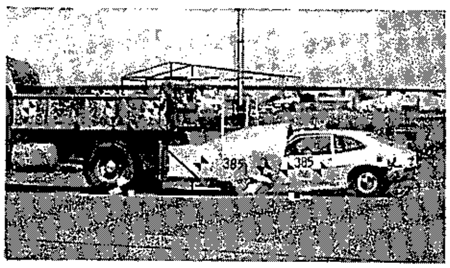


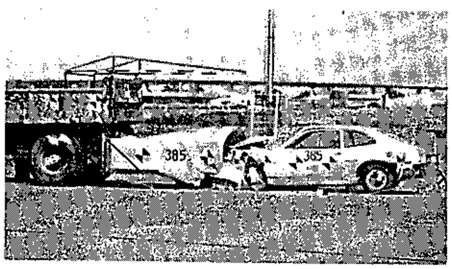
Impact +0.04 Sec.



Impact +0.09 Sec.



Impact +0.20 Sec.



Impact +1.45 Sec.

Test Date — May 7, 1981

Truck Mounted Attenuator Data

Type	Hexcel Aluminum Honeycomb
Size	7'Long x 7'-8"Wide x 2'High
Weight	280 lbs., TMA
	690 Lbs., Mounting Hardware

Truck Data

Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,000 lbs.

Car Data

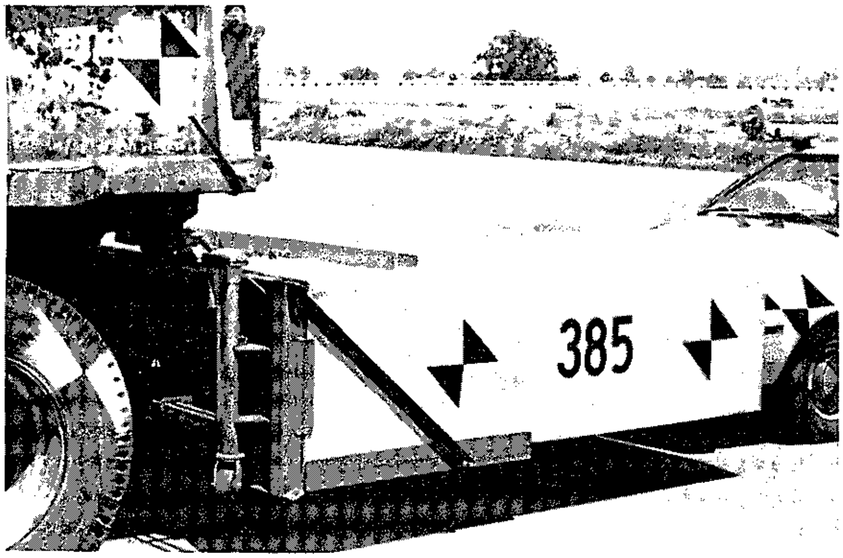
Model	1972 Ford Pinto
Impact Velocity	44.4 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	2180 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

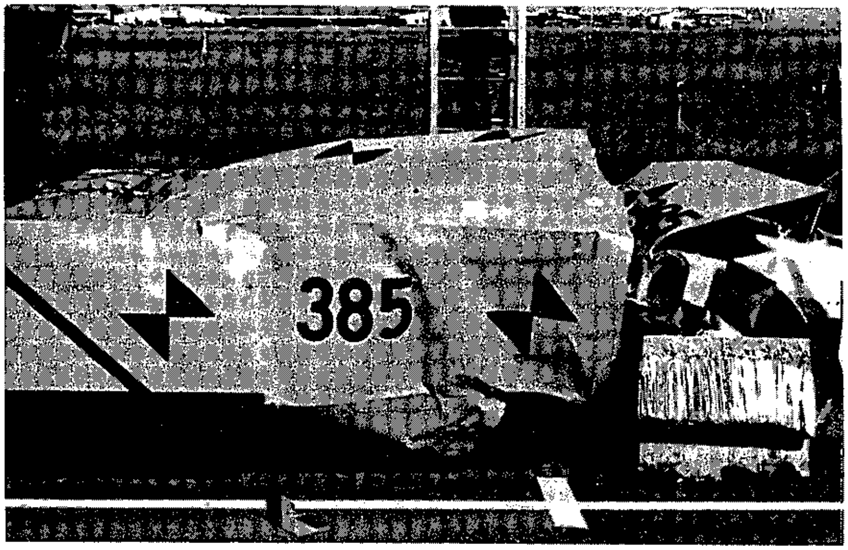
Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-15.2 g's
Car, Vertical	5.0 g's
Truck Longitudinal	2.4 g's
Dummy Head, Resultant, Car	-18.7 g's
Head Injury Criterion	173
Occupant Impact Velocity, Longitudinal	35.6 fps
Truck Roll Ahead Distance	6'-9"
Maximum Pitch, Car (Rear End)	2.75°
Maximum Rise, Truck Dump Body Rear	1.7 in.
TAD/VDI Index, Car	FD-5/12FDEW5

FIGURE 28

Test 385



Vehicles Before Impact

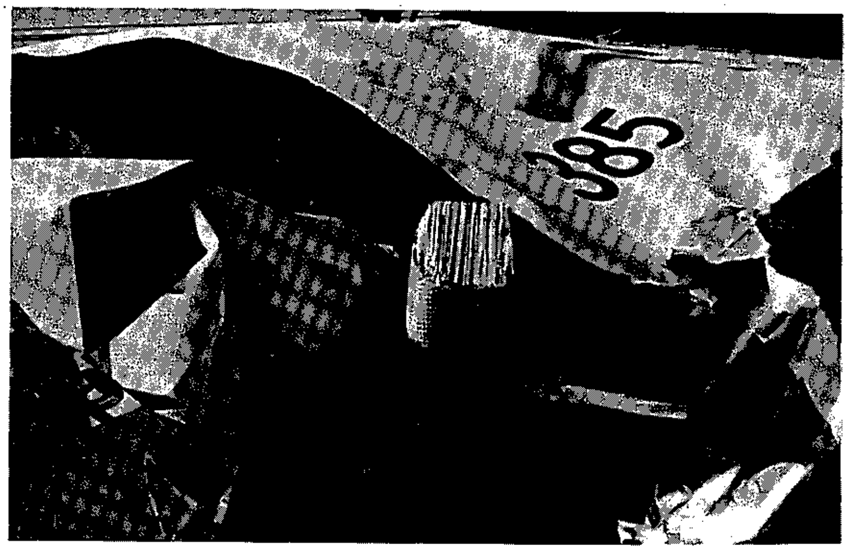


Final Positions of Vehicles

Crushed TMA Plywood End

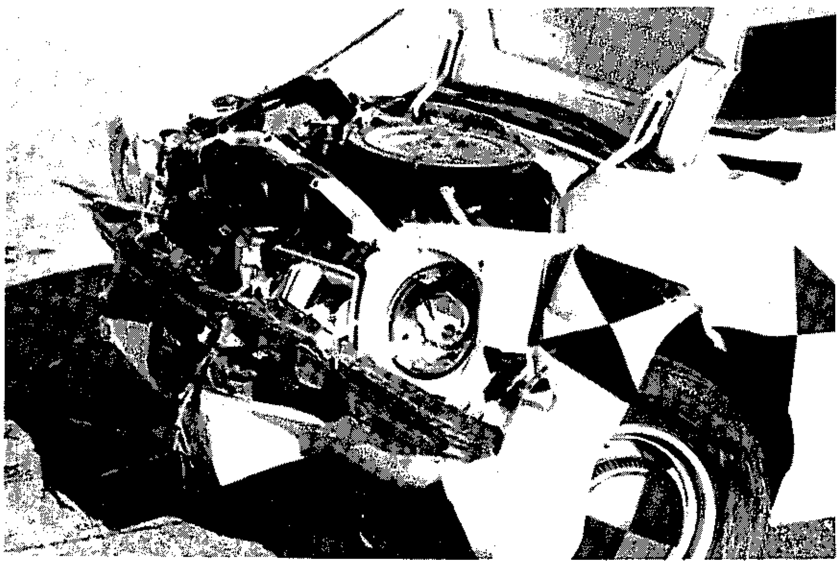
FIGURE 29

Test 385



TMA Damage

Car Penetrated TMA 52-Inches



Car Crushed 12-Inches

Truck Damage - 385: There was no truck damage.

TMA Damage - 385: Sixty percent of the honeycomb cells were damaged during the impact. The car penetrated a 60-inch width of the 92-inch wide of the TMA on center line. The penetration of the car was 52-inches into the TMA. The undercarriage was undamaged.

5.2.7 Test - 386

The purpose of Test 386 was to evaluate a heavy car impact with the redesigned TMA used in Test 385, a lightweight car impact. The supporting hardware was also redesigned to a lightweight configuration.

Car - 4230 lbs/45.1 mph 0° Head-On
Truck - 11000 lbs/rear wheels braked
TMA - 700 lbs.

The summary of the test data and photos of vehicles before and after impacts are shown in Figures 30 - 32.

Changes to TMA Design - 386: There were no changes in the TMA cell configuration design from Test 385. The mounting hardware was redesigned to a lighter weight configuration. A different attaching method for the TMA Box to the mounting hardware to eliminate the undercarriage was also incorporated.

Impact Description - 386: The car struck the TMA at the intended speed and angle on center line. There was little movement of the truck during the impact of the TMA. The car penetrated the TMA 74-inches. The car rolled ahead 17-feet after impact. The truck also rolled ahead 17-feet after impact. The pitching and yawing of the car during impact were minimal. The car and truck came to rest on center line of impact. TMA cell material and covering were scattered around the impact area.

Car Damage - 386: Damage to the front end body components was severe. The front of the car crushed back 11-inches. The radiator was moved back to the fan, the engine position was unchanged. The front doors were jammed, but easily opened. The door post columns were undamaged. The roof above the left door was slightly crimped. There was no interior damage. The windshield was intact. All tires were intact. The car had to be towed from the impact location.

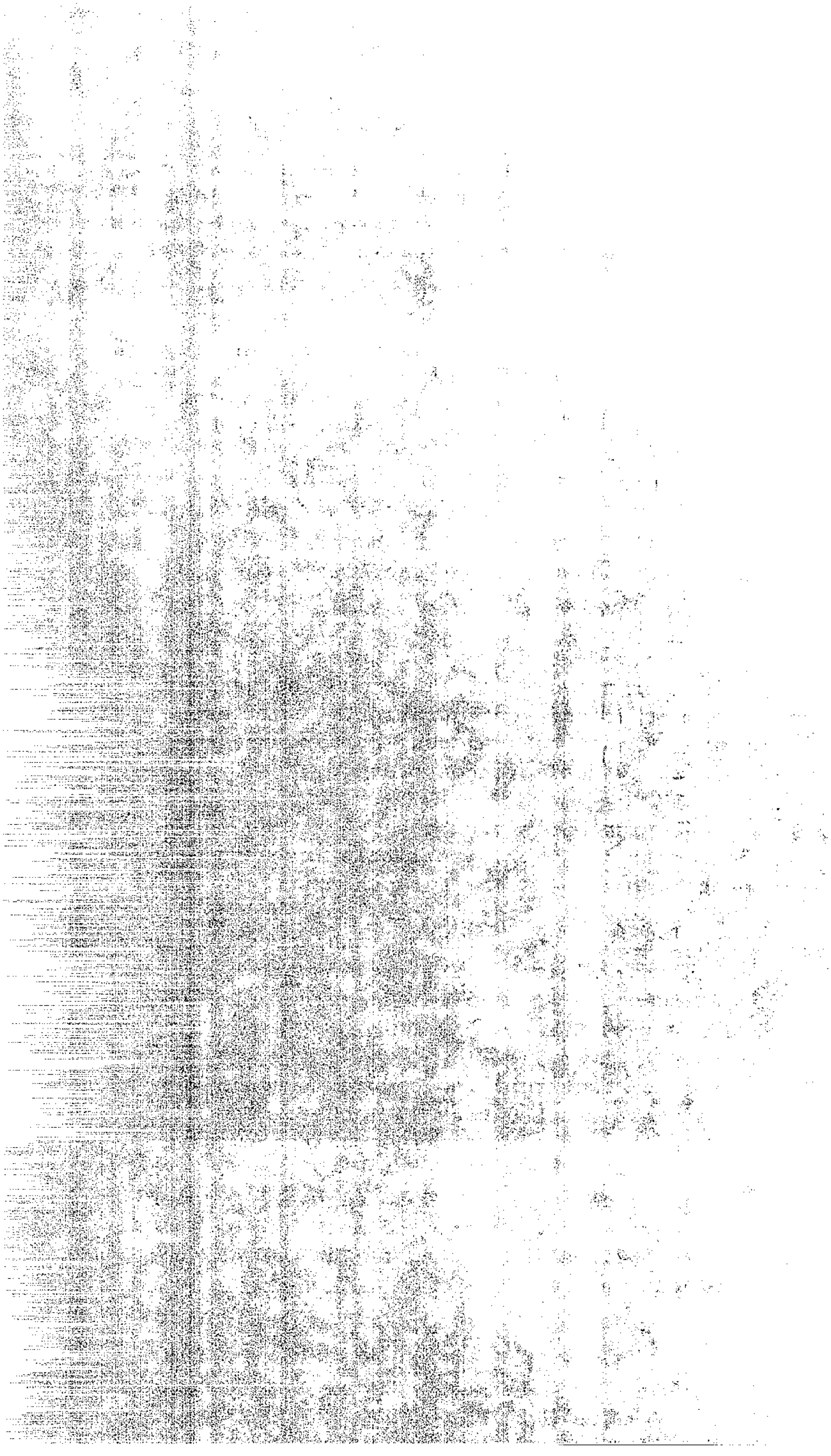
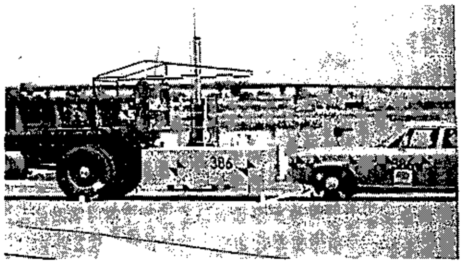
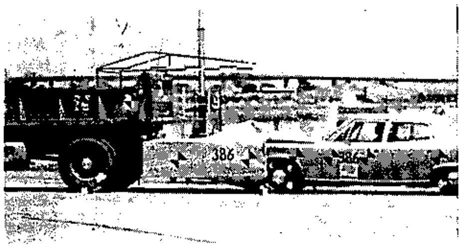


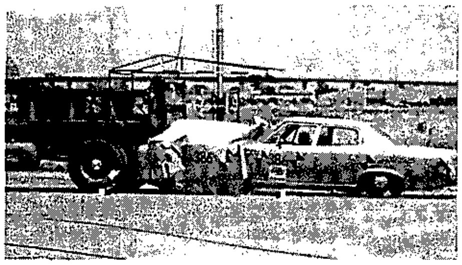
FIGURE 30 - DATA SUMMARY SHEET - TEST 386



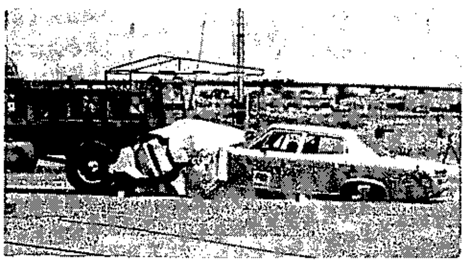
Impact -0.01 Sec.



Impact +0.04 Sec.



Impact +0.13 Sec.



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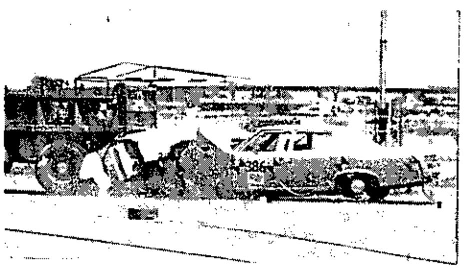


Impact +1.24 Sec.

Test Date	June 11, 1981

Truck Mounted Attenuator Data

Type	Hexcel Aluminum Honeycomb
Size	7'Long x 7'-8"Wide x 2'High
Weight	280 lbs., TMA 420 Lbs., Mounting Hardware

Truck Data

Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,000 lbs.

Car Data

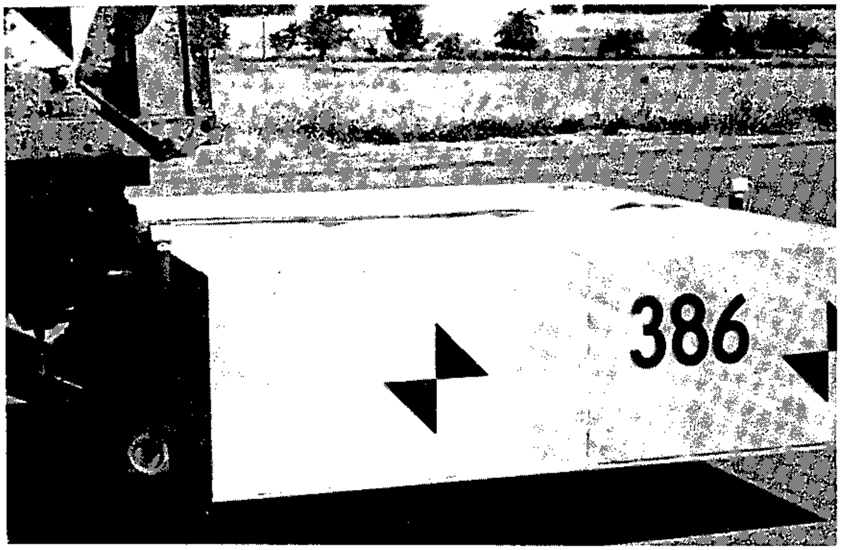
Model	1972 AMC Matador
Impact Velocity	45.1 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	4230 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-13.6 g's
Car, Vertical	6.1 g's
Truck Longitudinal	4.1 g's
Dummy Head, Resultant, Car	-13.4 g's
Head Injury Criterion	80
Occupant Impact Velocity, Longitudinal	32.4 fps
Truck Roll Ahead Distance	17'-0"
Maximum Pitch, Car (Rear End)	-3.5°
Maximum Rise, Truck Dump Body Rear	2.4 in.
TAD/VDI Index, Car	FD-4/12FDEW5

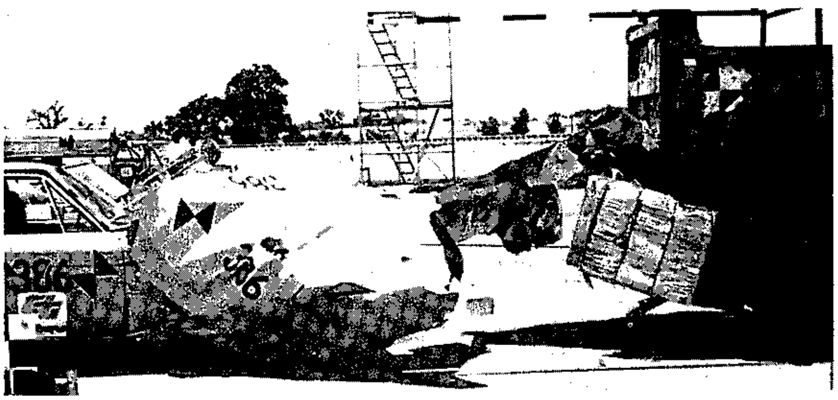
FIGURE 31

Test 386



TMA Before Impact

Lighweight Redesigned
TMA Support Hardware



TMA Covering (Skin)
Damage

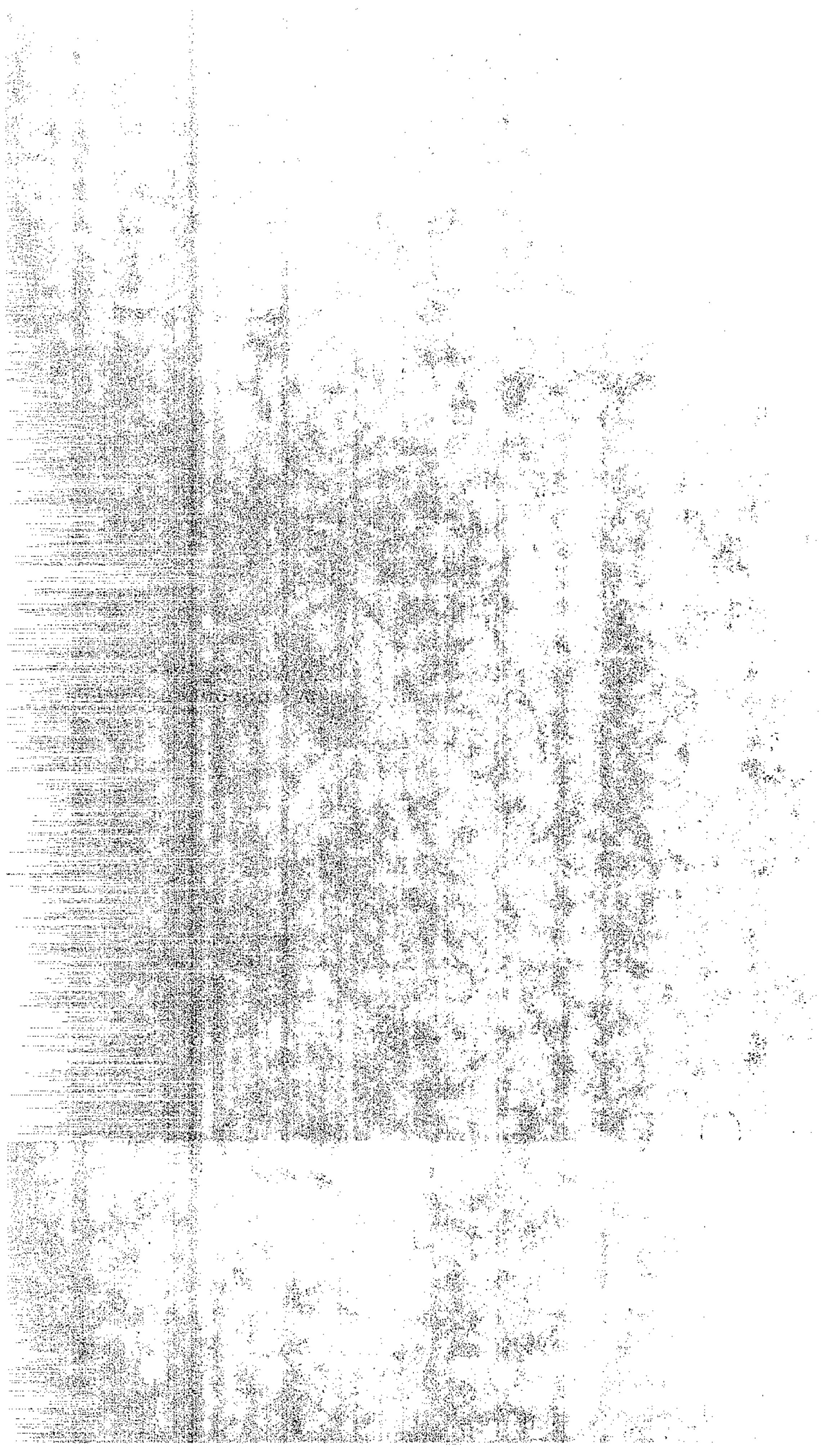
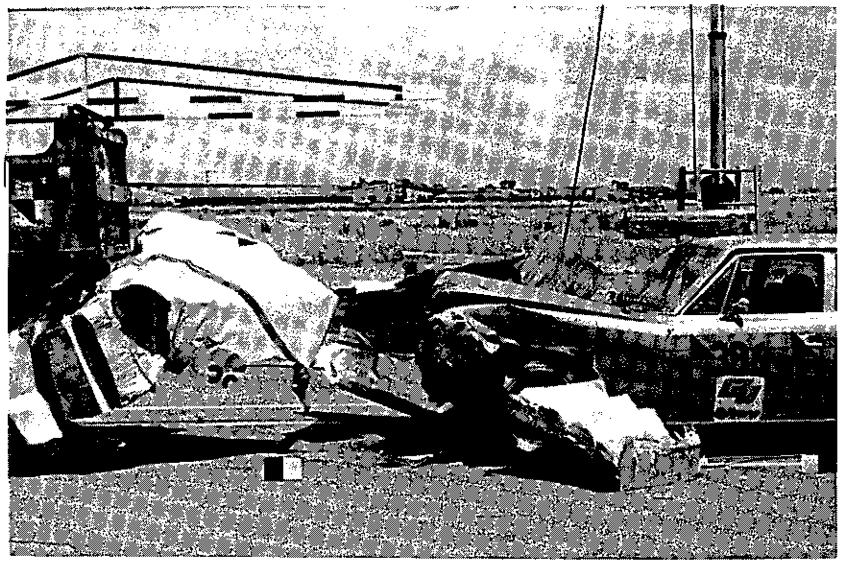
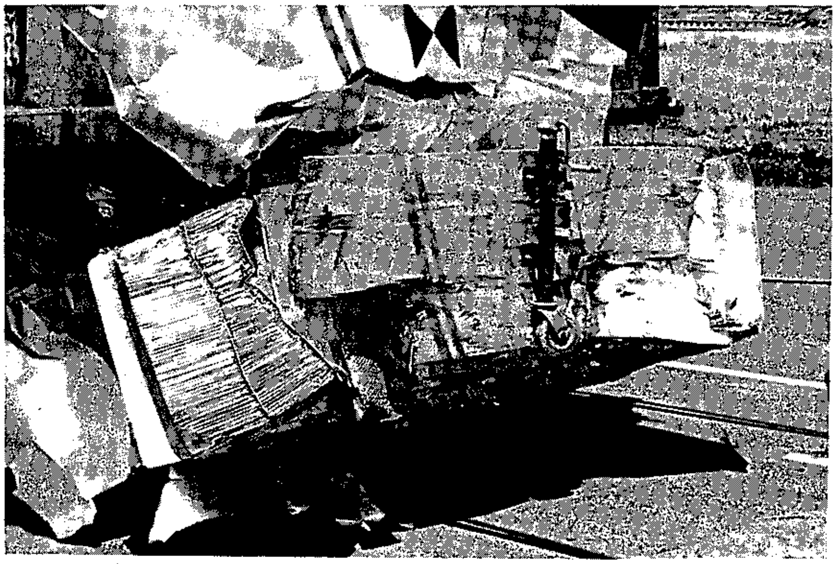


FIGURE 32

Test 386

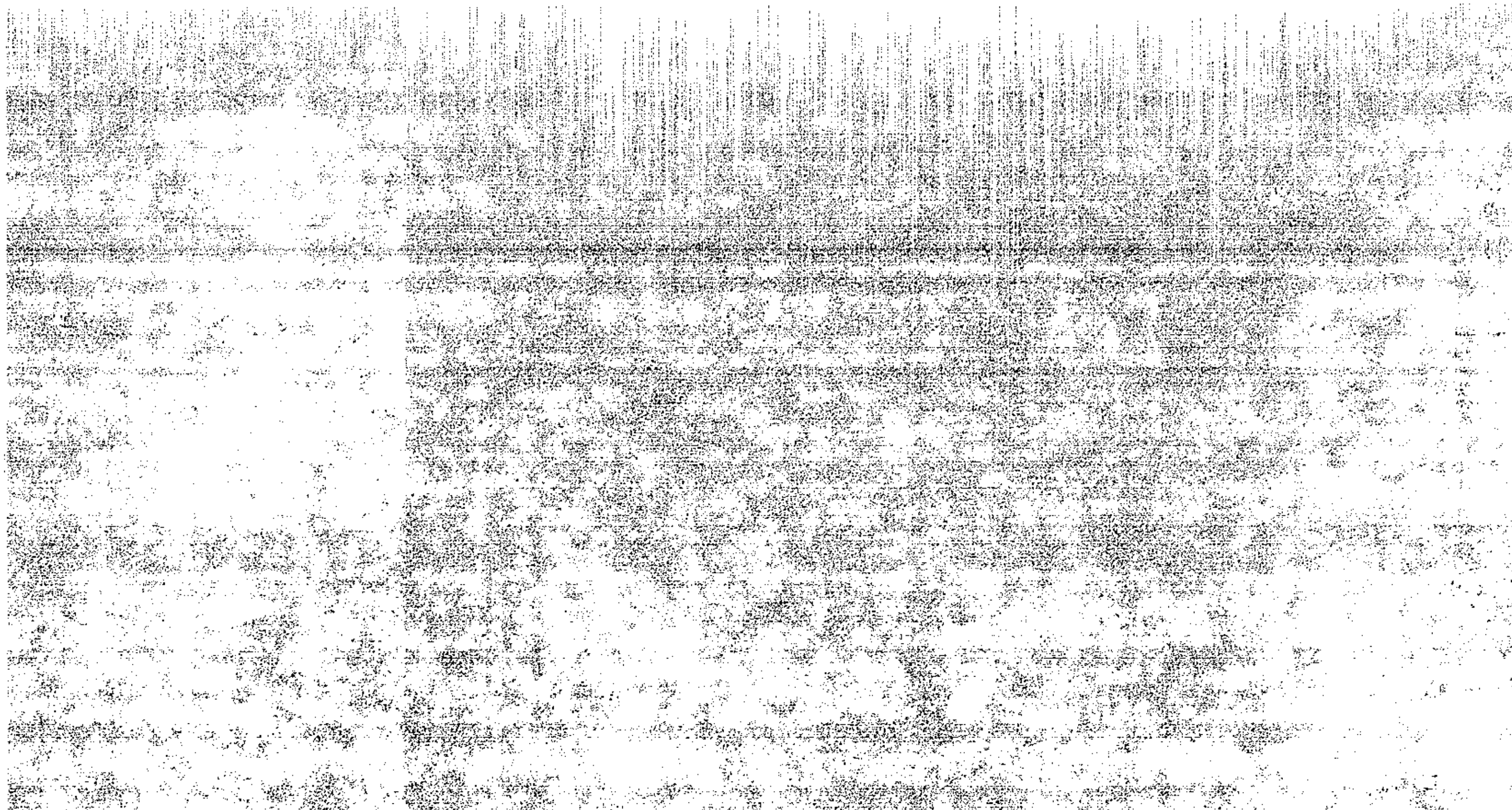


Vehicles Final Positions



TMA Completely Crushed, 74-Inches

Front Car Crush 11-Inches



MANAGEMENT [illegible]

[illegible]

Truck Damage - 386: There was no truck damage.

TMA Damage - 386: Ninety percent of the honeycomb cells was damaged during the impact. The lightweight support hardware did not fully support the last cell section. This resulted in the cell shearing at the narrower width of the backup support. This caused the TMA to come apart and honeycomb cell material to scatter about the impact area. Although the test results were acceptable, the backup support was redesigned to provide full width support for future tests. The mechanisms to raise and lower the TMA were not damaged.

5.2.8 Test - 387

The purpose of Test 387 was to evaluate a redesigned lightweight backup support. The redesigned unit would provide full width support for the TMA. The full width support was essential to provide for impacts that may occur off center line.

Car - 4190 lbs/45.5 mph 0° Head-On

Truck - 11000 lbs/rear wheel braked

TMA - 700 lbs.

The summary of the test data and photos of vehicles before and after impacts are shown in Figures 33 - 35.

Changes to TMA Design - 387: There were no changes in the TMA cell configuration from Test 386. The backup support was increased in width. This provided for a base for the cells to compress on and eliminate the possibility of the cell shearing at the edges of the narrow support as in Test 386. The raise-lower mechanisms were not changed.

Impact Description - 387: The car struck the TMA at the intended speed and angle on center line. There was little movement of the truck during impact of the TMA. The car penetrated the TMA 64-inches. The car rolled ahead 35-feet after impact. The truck rolled ahead 28-feet 8-inches after impact. There was no pitching or yawing of the car during impact. The car and truck came to rest on center line of impact. The attenuator covering engulfed the car containing all damaged TMA cell material. The impact area was free of debris.

[illegible]

FIGURE 33 - DATA SUMMARY SHEET - TEST 387

Test Date	August 11, 1981

Truck Mounted Attenuator Data

Type	Hexcel Aluminum Honeycomb
Size	7'Long x 7'-8"Wide x 2'High
Weight	280 lbs., TMA 420 Lbs., Mounting Hardware

Truck Data

Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,000 lbs.

No Photos Available

Car Data

Model	1972 AMC Matador
Impact Velocity	45.5 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	4190 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-14.4 g's
Car, Vertical	-4.6 g's
Truck Longitudinal	4.3 g's
Dummy Head, Resultant, Car	-15.6 g's
Head Injury Criterion	105
Occupant Impact Velocity, Longitudinal	34.5 fps
Truck Roll Ahead Distance	28'-8"
Maximum Pitch, Car (Rear End)	No Data
Maximum Rise, Truck Dump Body Rear	No Data
TAD/VDI Index, Car	FD-5/12FDEW5

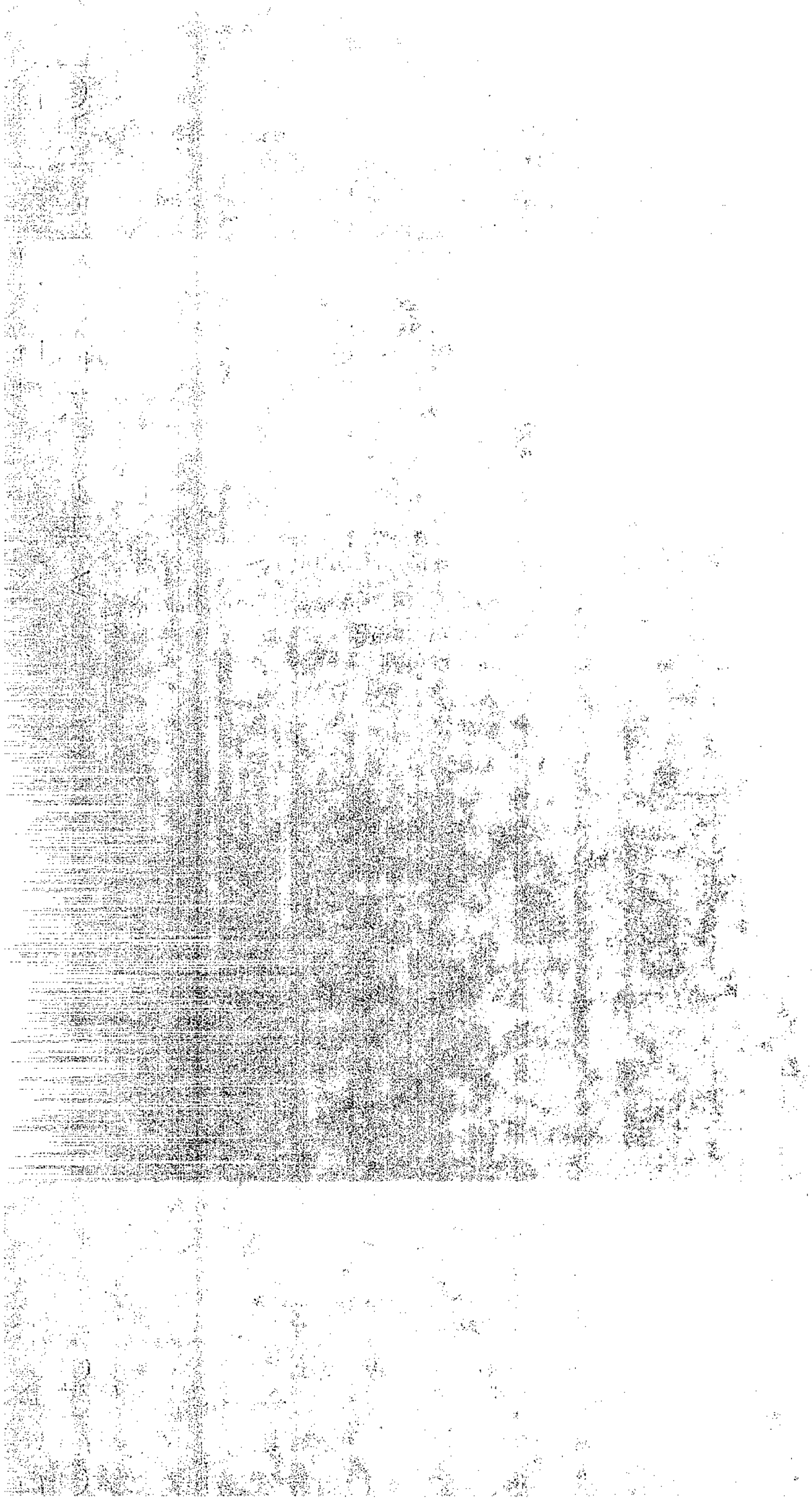
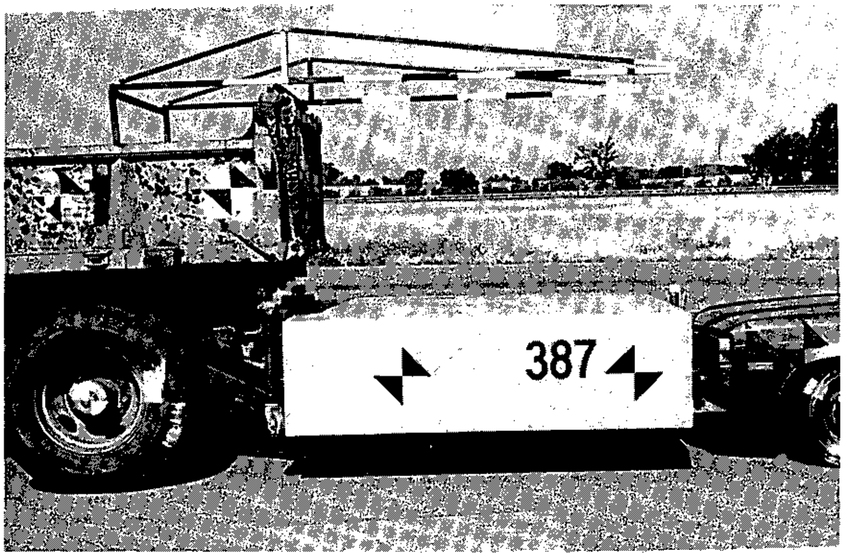
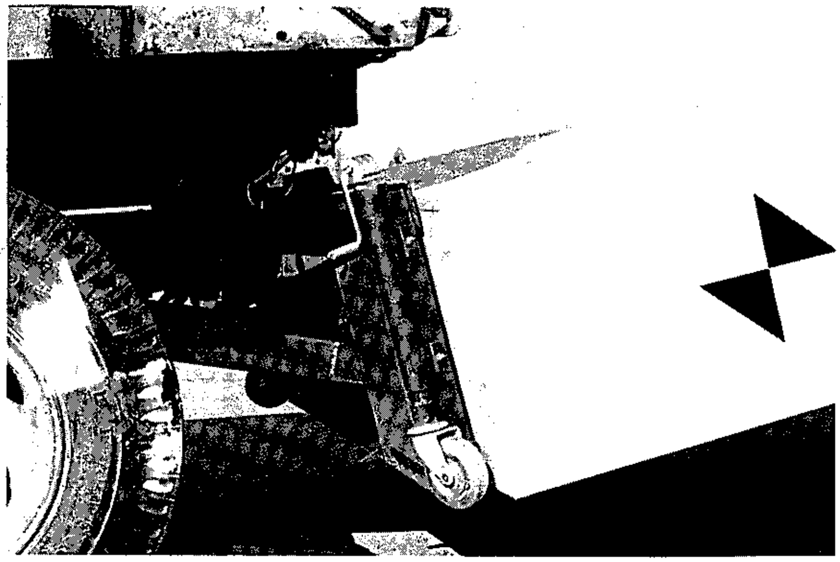


FIGURE 34

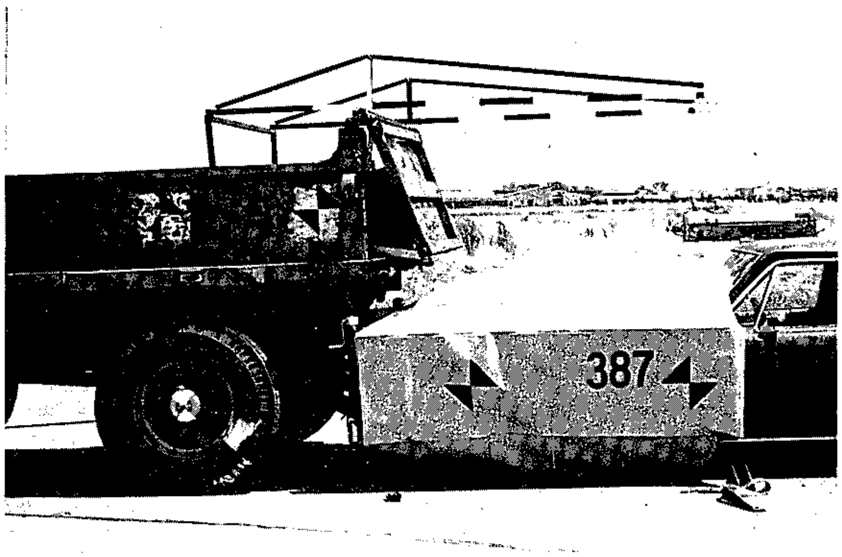
Test 387



Vehicles Before Impact



Redesigned Full Width TMA Support (Raised Position)



Final Position of Vehicles

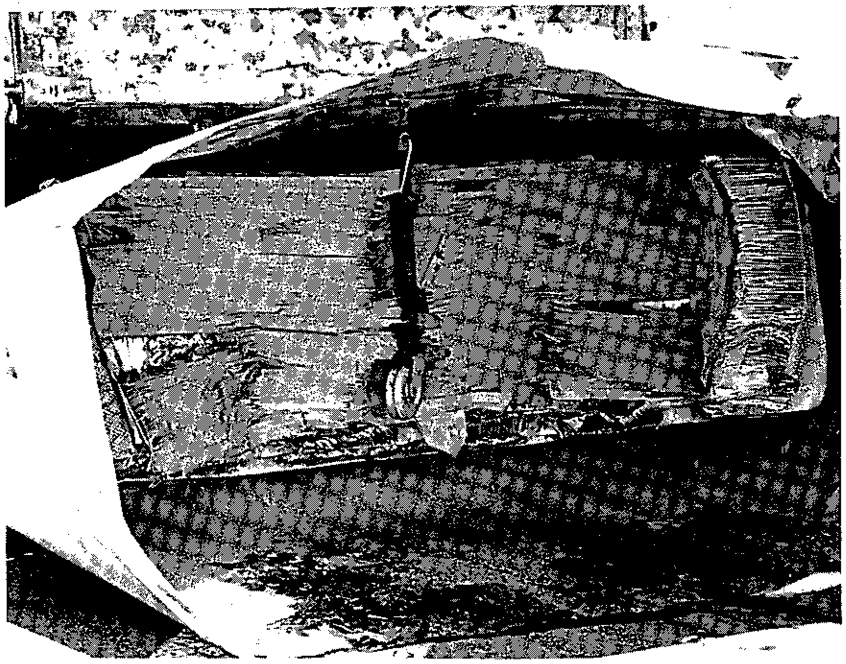
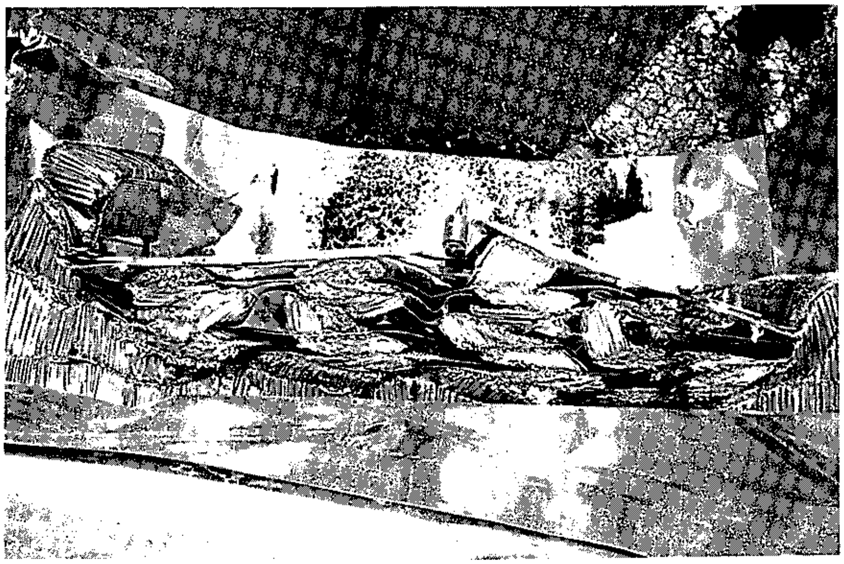


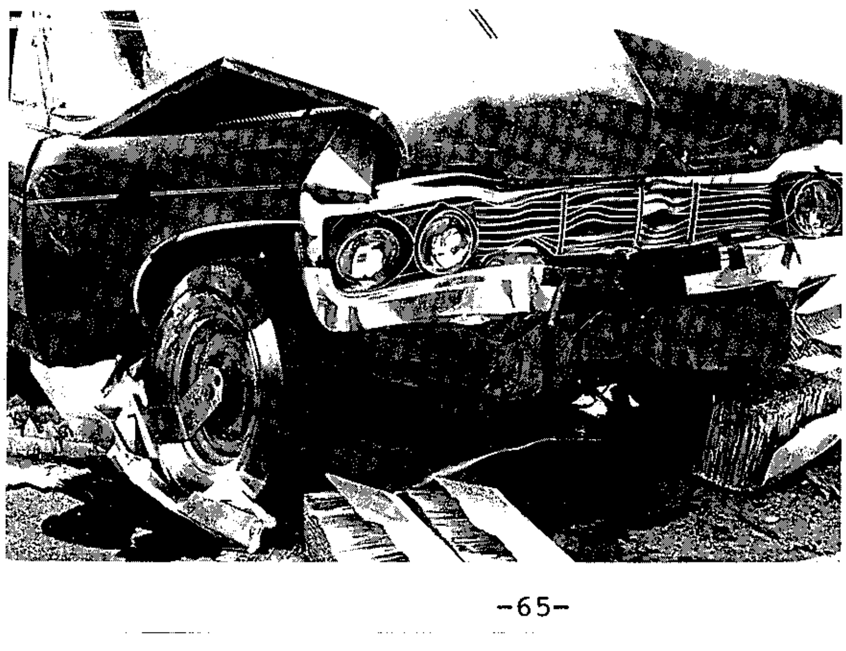
FIGURE 35

Test 387

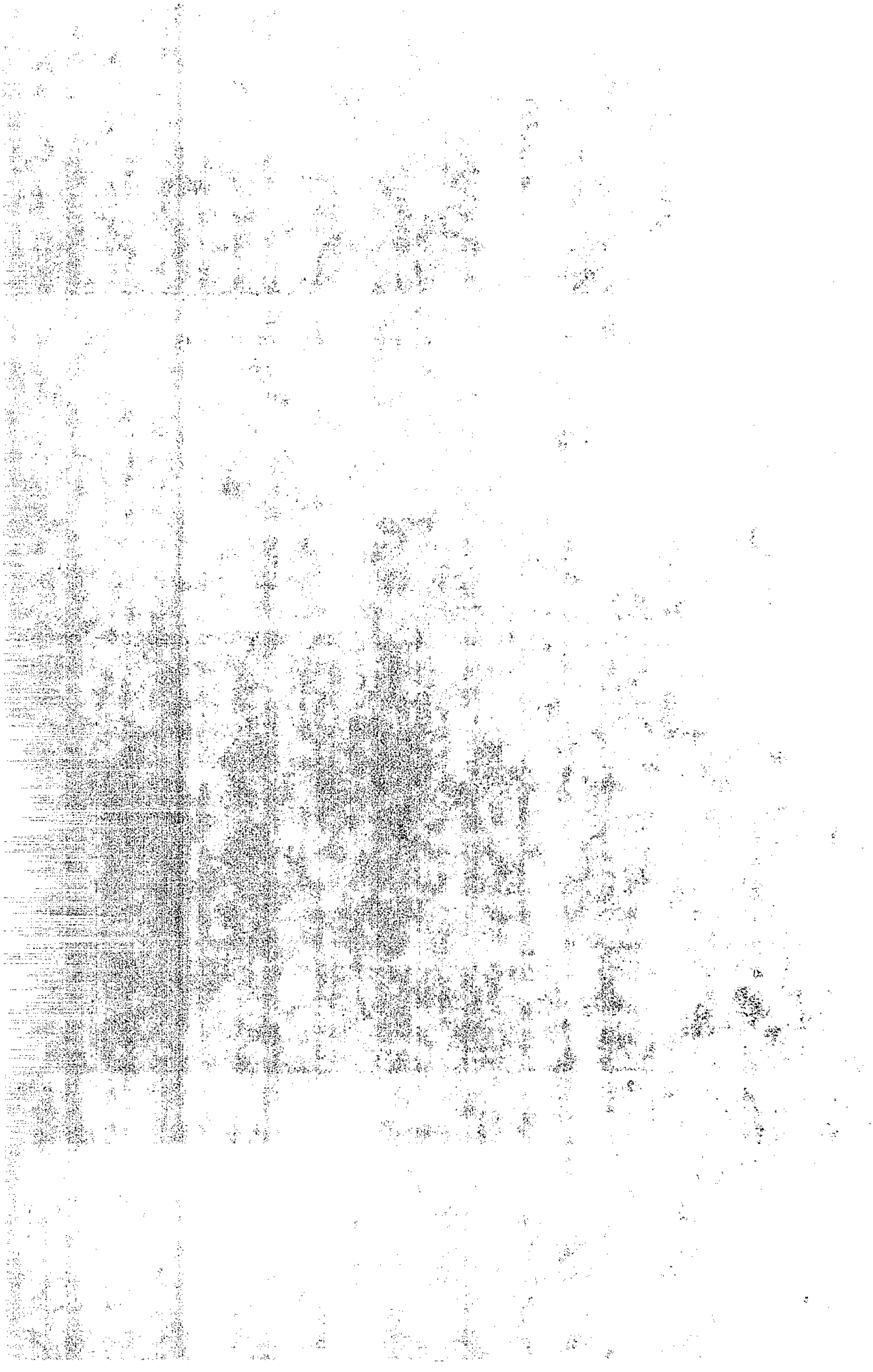
Three-quarter Inch Plywood is Used at Impacting End of TMA



TMA Crushed 64-Inches



Car Crushed 14-Inches



Car Damage - 387: Damage to the front end body components was severe. The front of the car crushed back 14-inches. The radiator was moved back to the fan. The engine position was unchanged. The front doors were jammed but easily opened. The roof above the door posts was crimped on both sides of car. There was no interior damage and no damage to instrumentation. The windshield was cracked from the lower right side to the upper center. Tires remained inflated. The car required towing from the impact location.

Truck Damage - 387: There was no truck damage.

TMA Damage - 387: Seventy-five percent of the honeycomb cells were damaged during the impact. The redesigned lightweight support hardware was not damaged. The raise lower mechanism was not damaged.

5.2.9 Test - 388

The purpose of Test 388 was to evaluate a slight modification to the TMA.

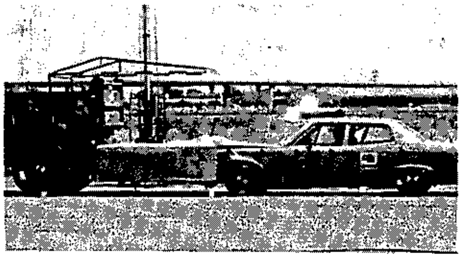
Car - 4185 lbs/46.4 mph 0° Head-On
Truck - 11000 lbs/rear wheel braked
TMA - 700 lbs.

The summary of the test data and photos of vehicles before and after impacts are shown in Figures 36-38.

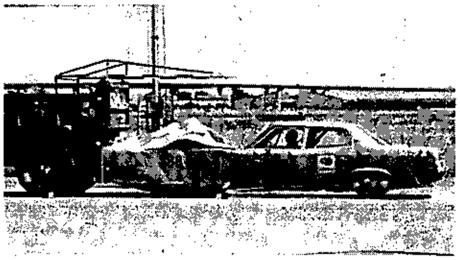
Changes to TMA Design - 388: The TMA attachment to the support hardware design was modified to allow additional crush of the last section of the TMA. The unit used in Test 387 had mounting stud bulkheads in the last section that were spaced at about the same width as the impacting car frame. On impact the car bottomed on these which did not allow any crush of the last section of honeycomb. To eliminate this problem the mounting stud bulkheads were moved out from 40-inches to 70-inches. This would assure that during any impact it would not be possible for the rigid frame members of the impacting vehicle to bottom on both bulkheads. This modification allowed approximately 6-inches additional crush.

Impact Description - 388: The car struck the TMA on center line at the intended speed and angle. There was little movement of the

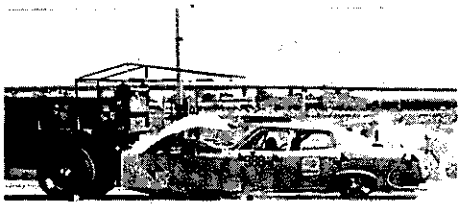
FIGURE 36 - DATA SUMMARY SHEET - TEST 388



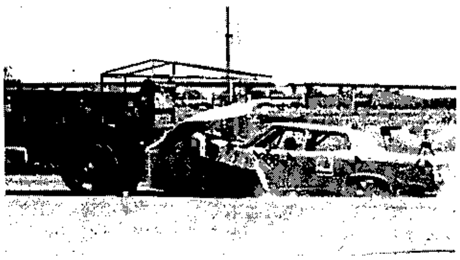
Impact +0.02 Sec.



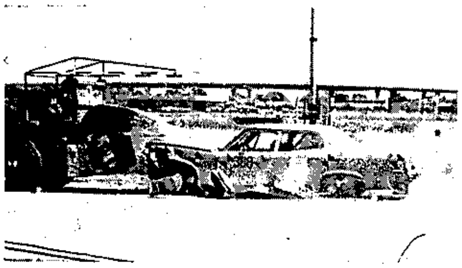
Impact +0.07 Sec.



Impact +0.12 Sec.



Impact +0.21 Sec.



Impact +0.80 Sec.

Test Date	August 27, 1981

Truck Mounted Attenuator Data

Type	Hexcel Aluminum Honeycomb
Size	7'Long x 7'-8"Wide x 2'High
Weight	280 lbs., TMA
	420 Lbs., Mounting Hardware

Truck Data

Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,000 lbs.

Car Data

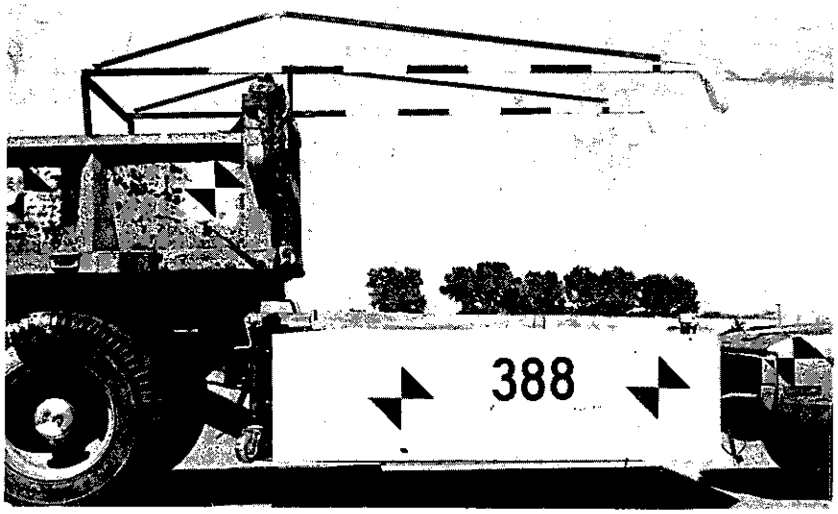
Model	1972 AMC Matador
Impact Velocity	46.4 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	4185 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

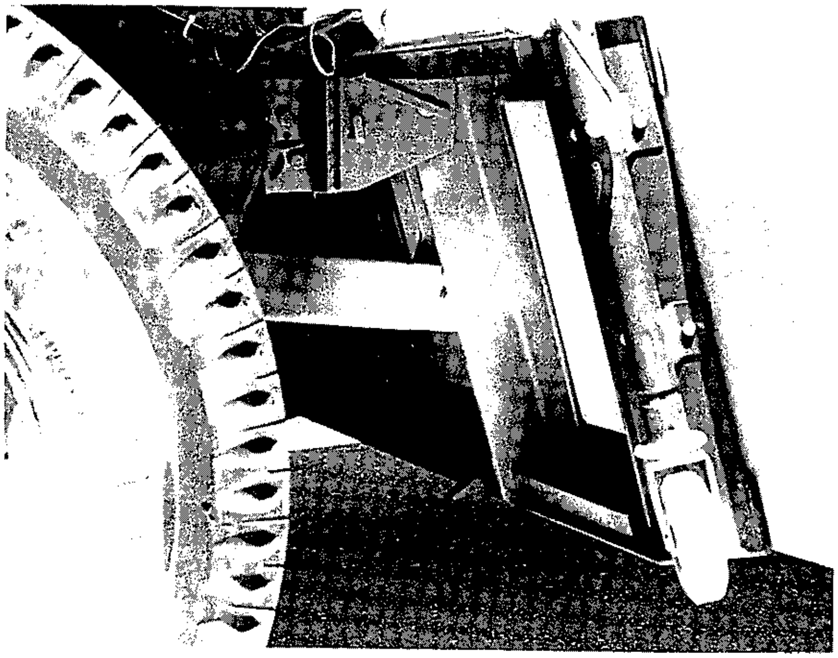
Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-13.8 g's
Car, Vertical	-5.2 g's
Truck Longitudinal	4.3 g's
Dummy Head, Resultant, Car	-15.0 g's
Head Injury Criterion	66
Occupant Impact Velocity, Longitudinal	33.3 fps
Truck Roll Ahead Distance	39'-9"
Maximum Pitch, Car (Rear End)	+4.0°
Maximum Rise, Truck Dump Body Rear	3.2 in.
TAD/VDI Index, Car	FD-5/12FDEW5

FIGURE 37

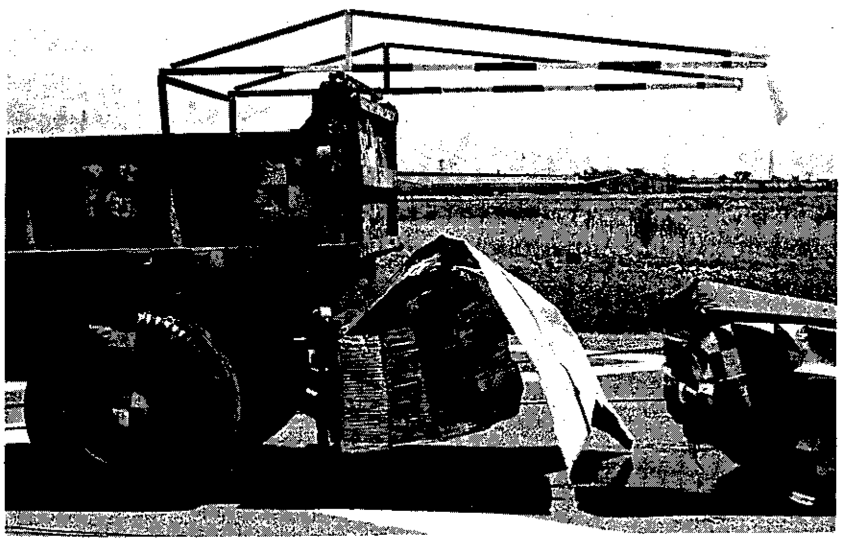
Test 388



Vehicles Before Impact



TMA Lightweight Support



Vehicles Final Positions

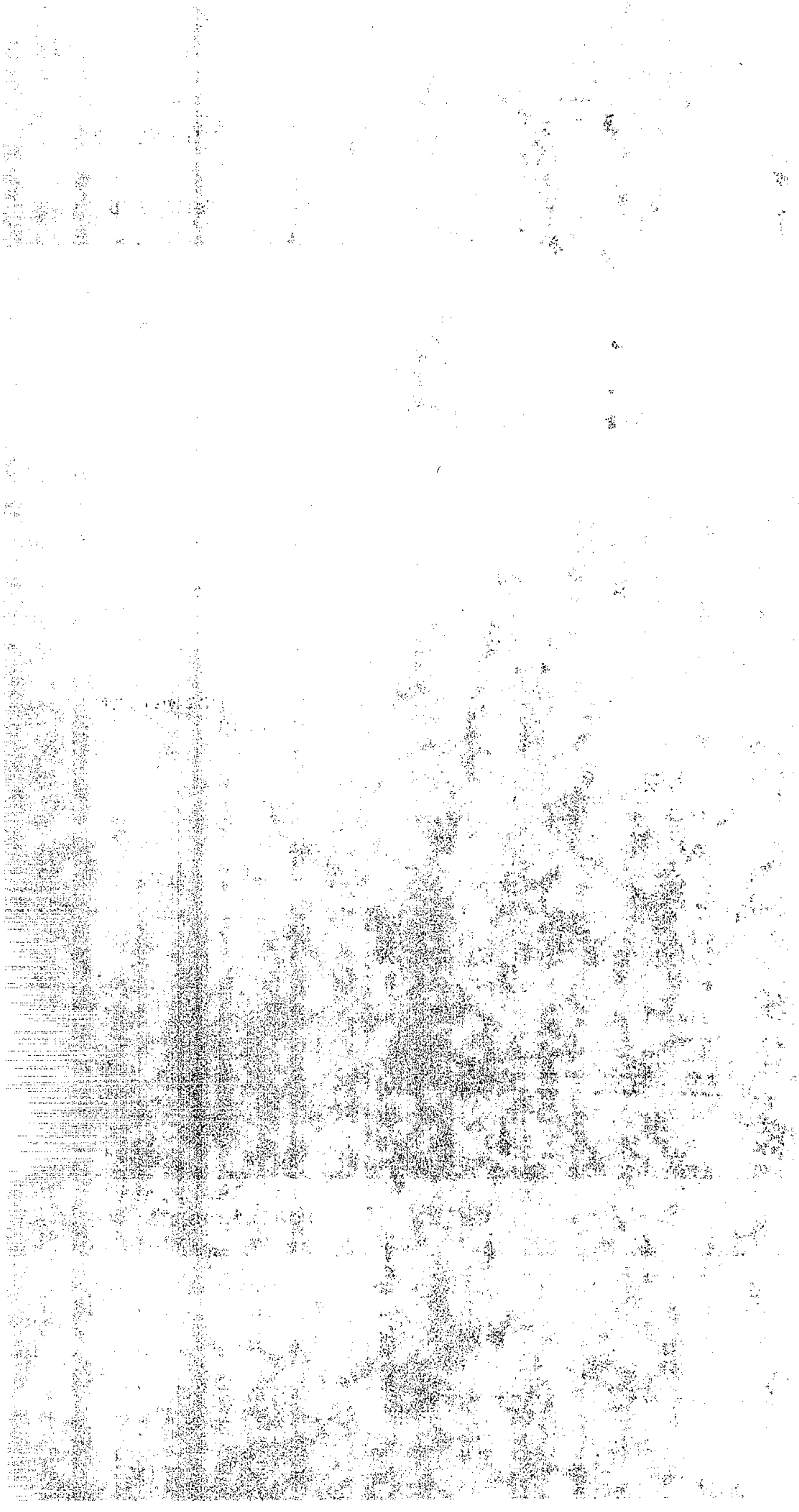
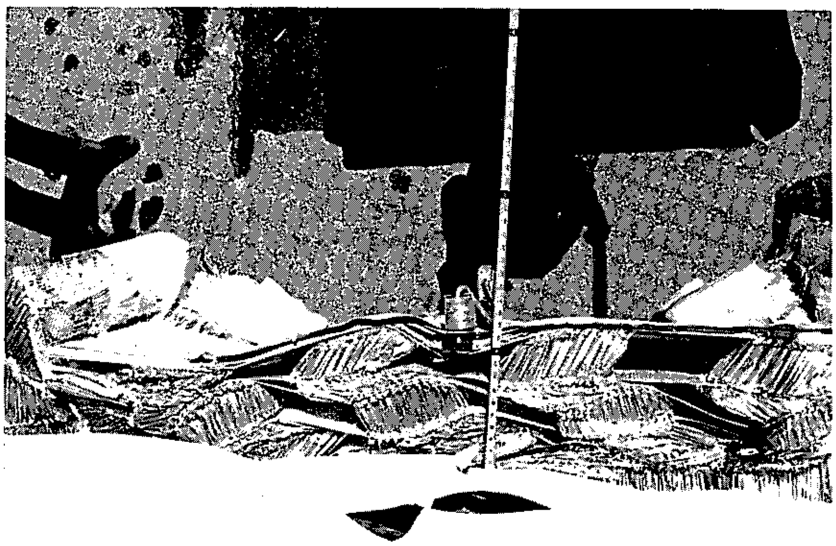


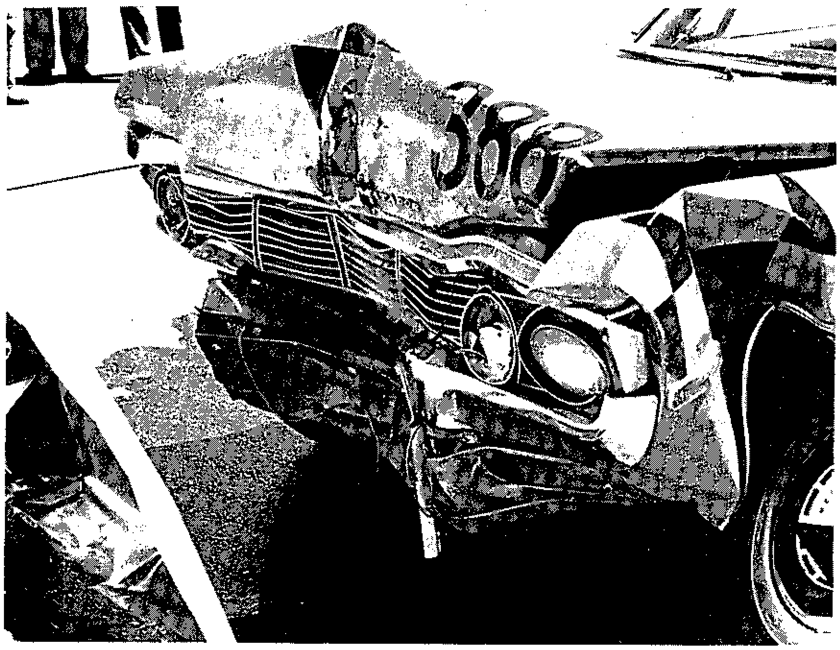
FIGURE 38

Test 388

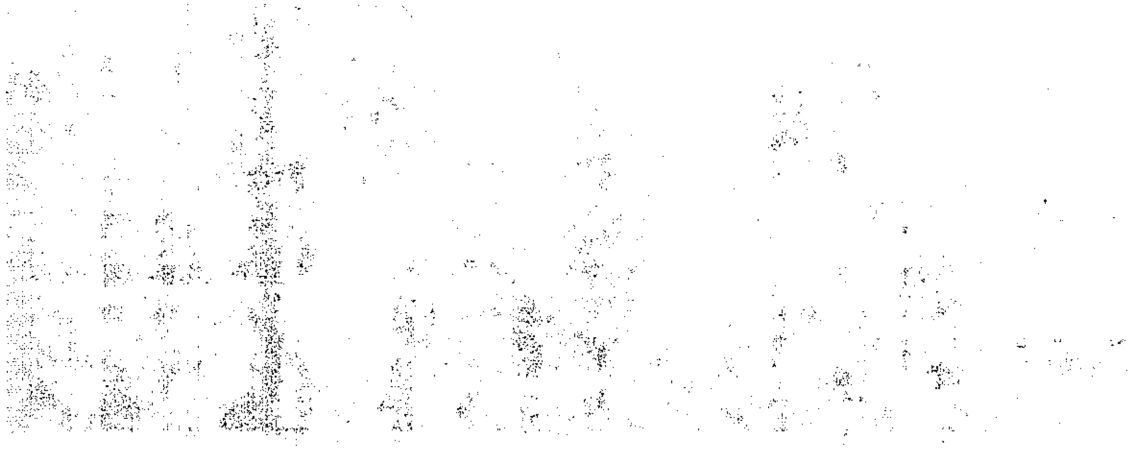
Vehicles Final Positions

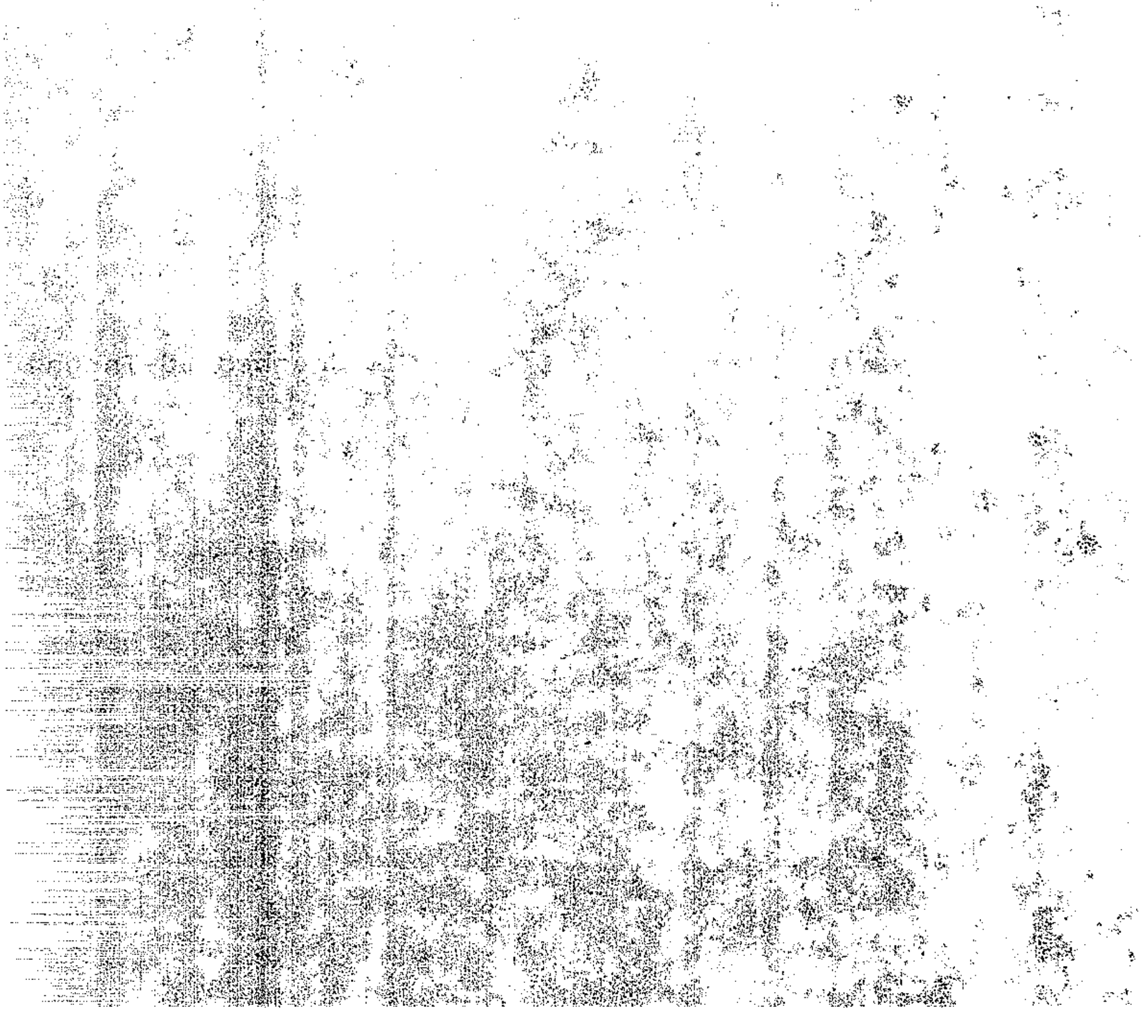


TMA Crushed 68-Inches



Car Crushed 12-Inches





truck during the impact. The car penetrated the TMA 68-inches. The car rolled ahead 41-feet after impact. The truck rolled ahead 39-feet 9-inches after impact. Pitching and yawing of the car was minimal. The vehicles came to rest on the impact center line. The impact area was free of debris.

Car Damage - 388: Damage to the front body compoeenents was severe. The front of the car crushed back 12-inches. The radiator was moved back to the fan. The position of the engine was unchanged. The front doors were jammed but easily opened. Door posts were undamaged. The roof above the door post on the left side of the car was slightly crimped. There was no damage on the interior. The windshield was intact. Tires remained inflated. The car was towed from the impact location.

Truck Damage - 388: There was no truck damage.

TMA Damage - 388: Eighty-one percent of the honeycomb cells were damaged during the impact. There was no damage to the support hardware. The relocated mounting stud bulkheads allowed additional crush of the TMA cell.

5.2.10 Test - 389

The purpose of Test 389 was to evaluate the acceptable TMA design used in Test 388 in an angle impact off center line.

Car - 4270 lbs./44.8 mph 10° angle of 1-foot left of center line
Truck - 11,000 lbs./rear wheels braked
TMA - 700 lbs.

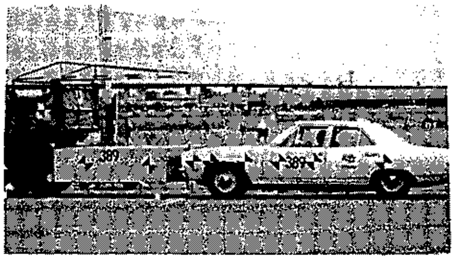
The summary of the test data and photos of vehicles before and after impacts are shown in Figures 39 - 41.

Changes to TMA Design - 389: There were no changes to the TMA design from Test 388.

Impact Description - 389: The car struck the TMA at the desired speed and location. There was little movement of the truck during

FIGURE 39 - DATA SUMMARY SHEET - TEST 389

Test Date September 24, 1981



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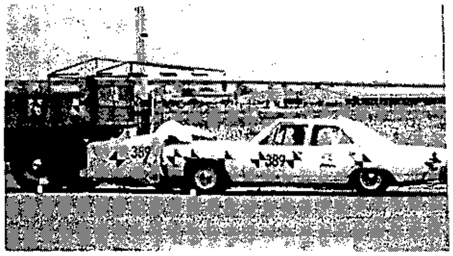
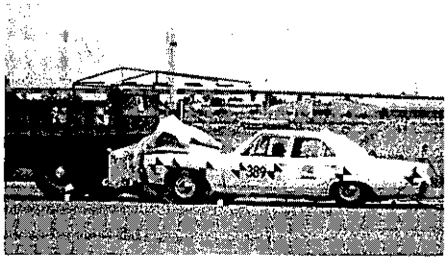
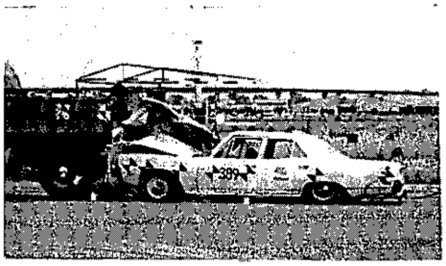


Impact +0.06 Sec.



Impact +0.11 Sec.



Impact +0.22 Sec.

Impact +1.19 Sec.

Truck Mounted Attenuator Data

Type	Hexcel Aluminum Honeycomb
Size	7'Long x 7'-8"Wide x 2'High
Weight	280 lbs., TMA
	420 Lbs., Mounting Hardware

Truck Data

Model	Ford F750 Dump Truck
Gross Vehicle Weight	Rated 25,000 lbs.
Dump Body Capacity	4 Cu. Yds.
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	2nd Gear
Weight (W/O TMA)	11,000 lbs.

Car Data

Model	1970 Plymounth Belvedere
Impact Velocity	44.8 mph
Impact Angle	12°, Car ℄ Offset 1'-0" from Truck ℄
Weight (W/O Dummy)	4270 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-10.6 g's
Car, Vertical	4.6 g's
Truck Longitudinal	No Data
Dummy Head, Resultant, Car	-11.8 g's
Head Injury Criterion	65
Occupant Impact Velocity, Longitudinal	29.1 fps
Truck Roll Ahead Distance	14'-3" Forward and 1'-9" to the right
Maximum Pitch, Car (Rear End)	+3.75°
Maximum Rise, Truck Dump Body Rear	3.3 in.
TAD/VDI Index, Car	FD-4/01FDEW5

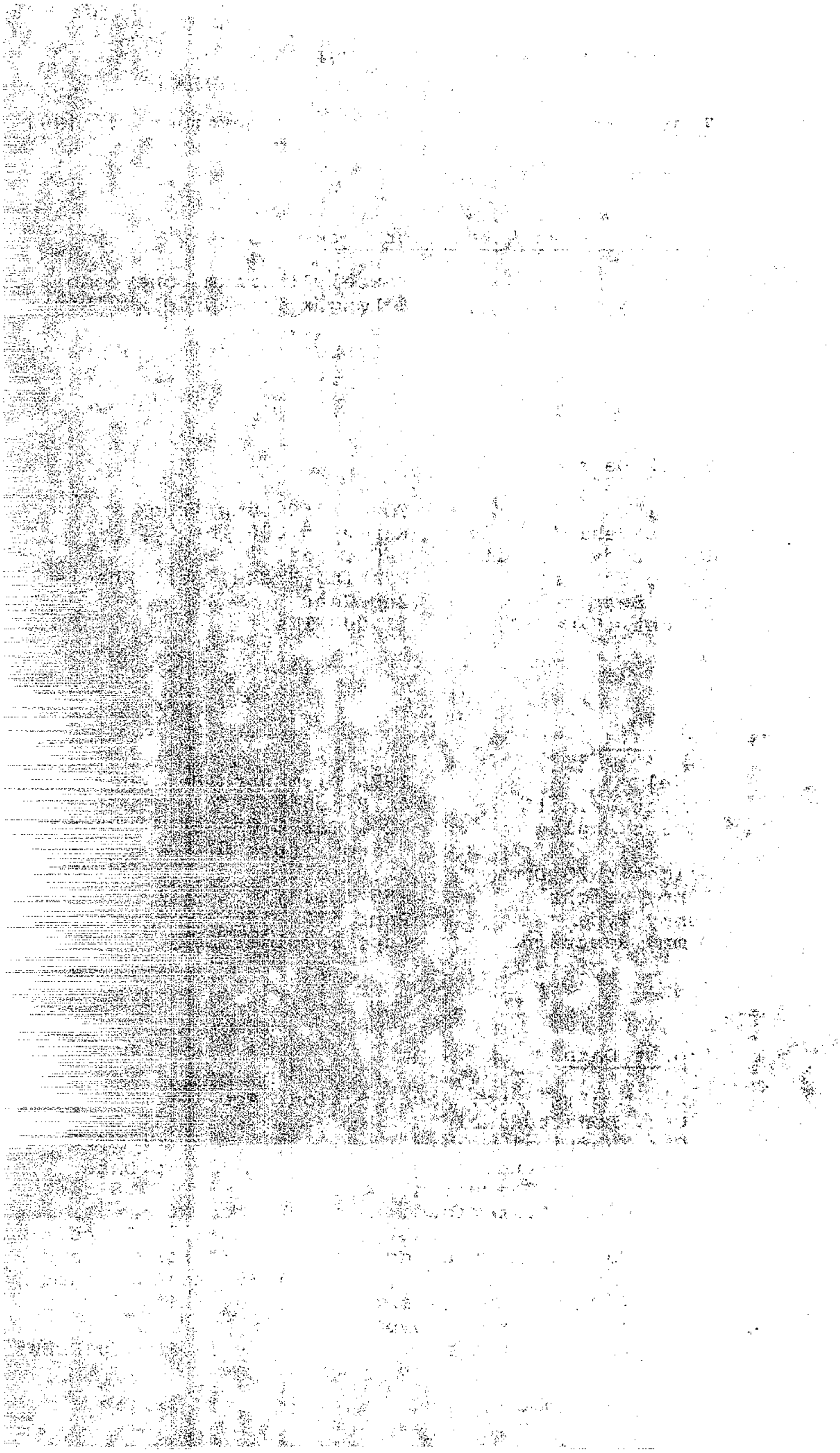
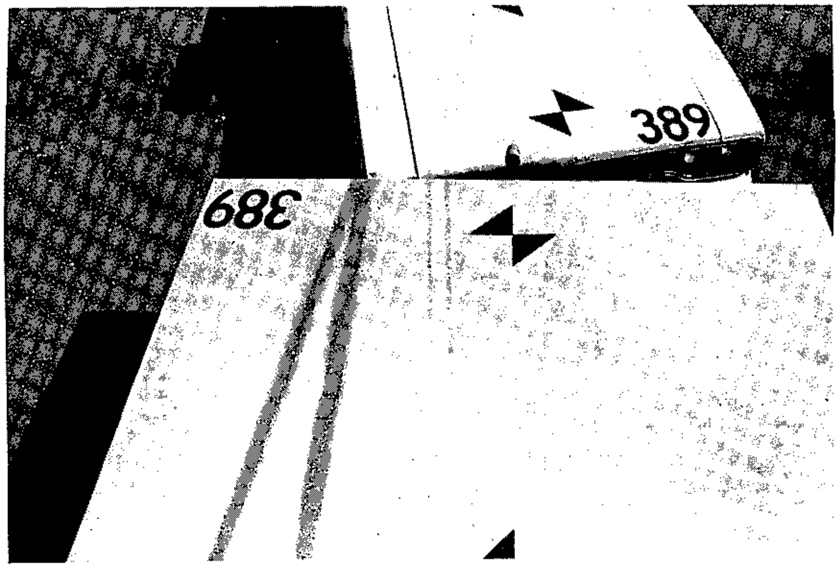
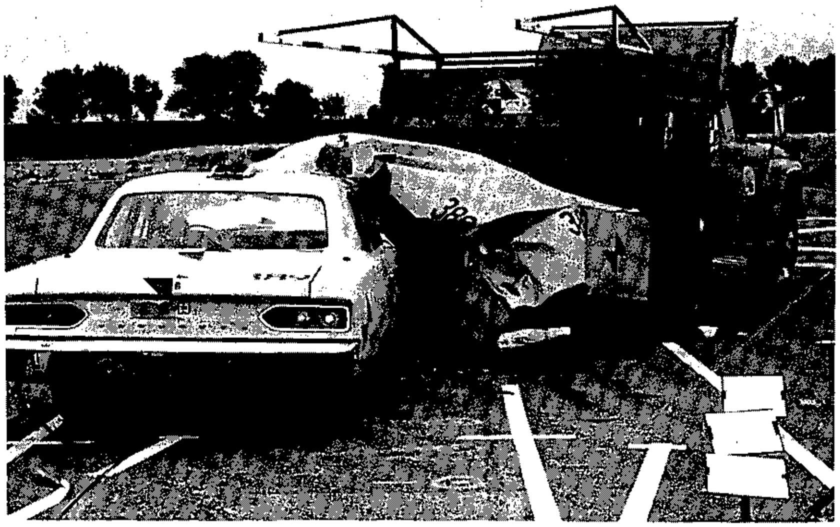


FIGURE 40

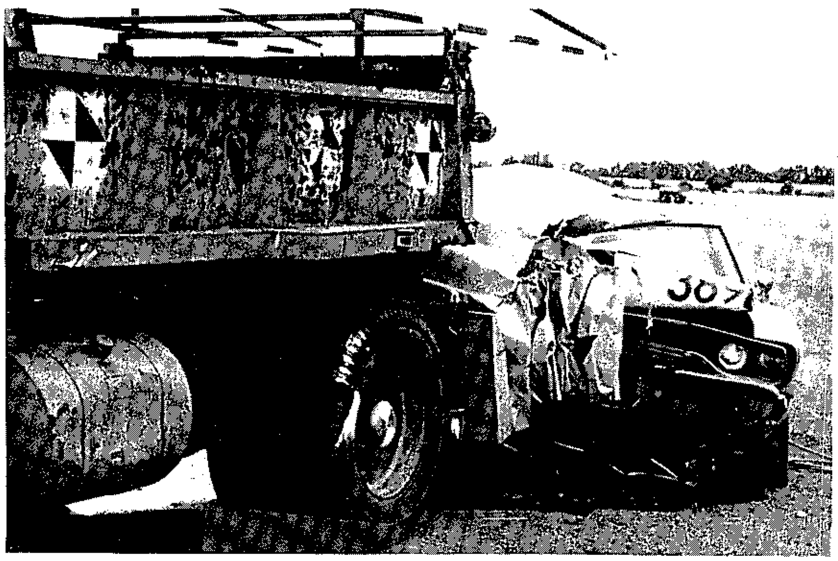
Test 389



Car and TMA Before Impact 10° Angle, 1-Foot Left of Center Line



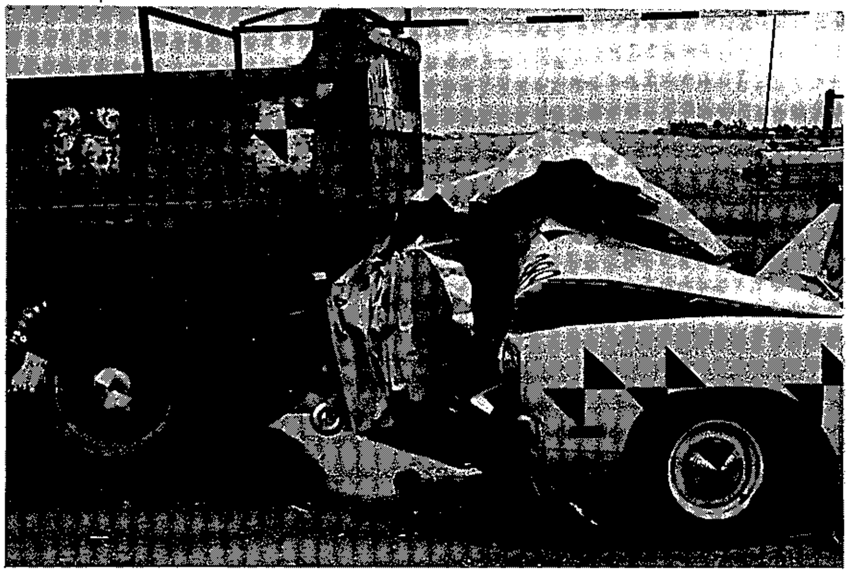
Vehicles Final Positions



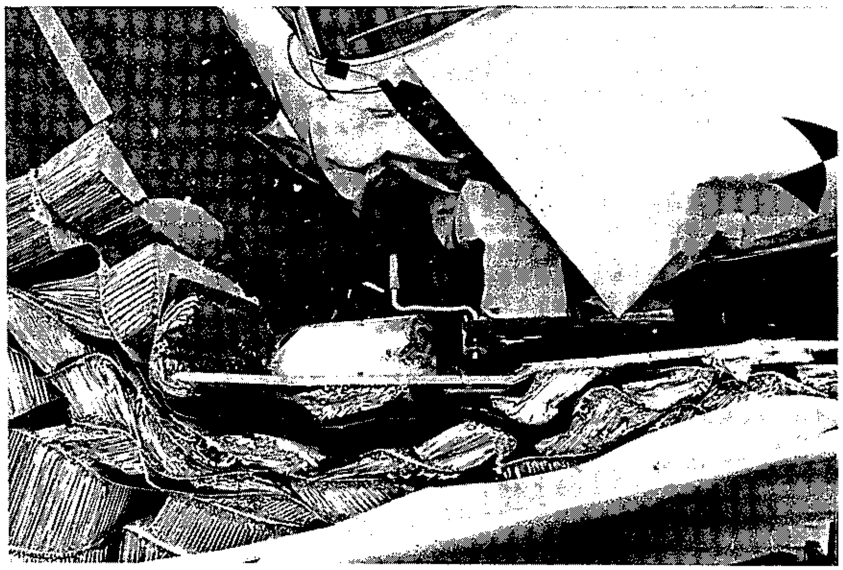
Vehicles Final Positions

FIGURE 41

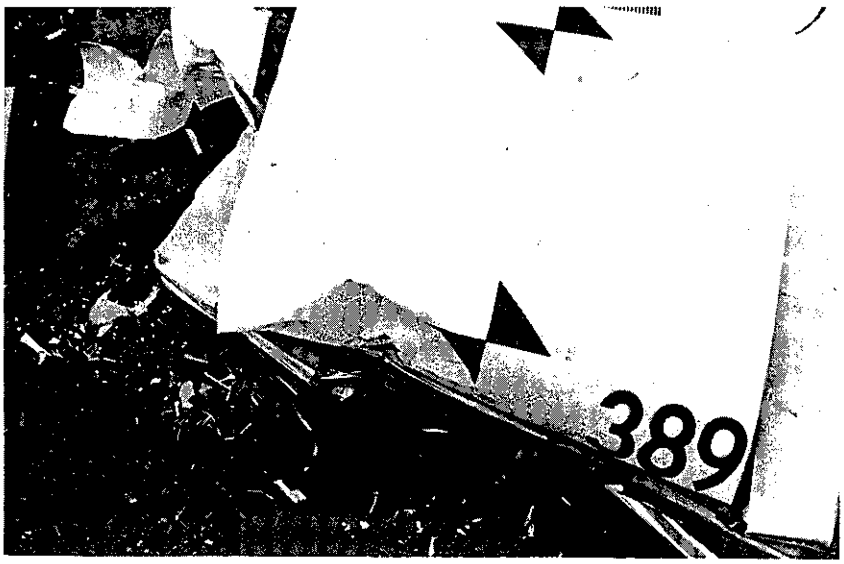
Test 389



There was no Crush on the Left Side of the Car



The TMA Crushed 66-Inches on the Left Side



The Car Crushed 24-Inches on the Right Side

the impact. The car penetrated the TMA 66-inches on the left side and 36-inches on the right side. The truck rolled ahead 14-feet 3-inches, and turned to the right 12 degrees. The car rolled ahead 23-feet 2-inches and 1-foot to the left of and parallel with the impact center line. The impact area was free of debris.

Car Damage - 389: Damage to the front of the car was confined to the right front corner. The right front of the car was crushed back 24-inches, the left front was not crushed back. The radiator was crushed back to the fan. Engine position was unchanged. Doors and door posts were not damaged. The roof above the right door post was crimped. In the interior, the right side of the dashboard was slightly deformed. The windshield was intact. All tires were intact. The car required towing from the impact location.

Truck Damage - 389: There was no truck damage.

TMA Damage - 389: Sixty percent of the honeycomb cells were damaged during the impact. The entire TMA was held together by the covering after impact. The lightweight backup support deflected 1-inch on the left side due to the angle impact. The raise lower mechanism was not damaged.

5.3 Pickup Mounted Attenutor Test Results

Accelerometers records from cars, trucks, and head of the dummy are contained in Appendix C. A film report has been made which shows all PMA tests.

5.3.1 Test - 391

Car - 4290 lbs/43.9 mph/0° Head-On

Pickup - 4415 lbs/rear wheels braked/No PMA

The summary of test data and photos of the vehicles before and after impact are shown in Figures 42-44.

Impact Description - 391: The car struck the rear of the pickup at the intended speed and angle. The front of the car was crushed back 20-inches. Upon impact the pickup bumper broke free and the car submarined under the rear of the pickup. This allowed the car to impact the rear differential housing of the pickup

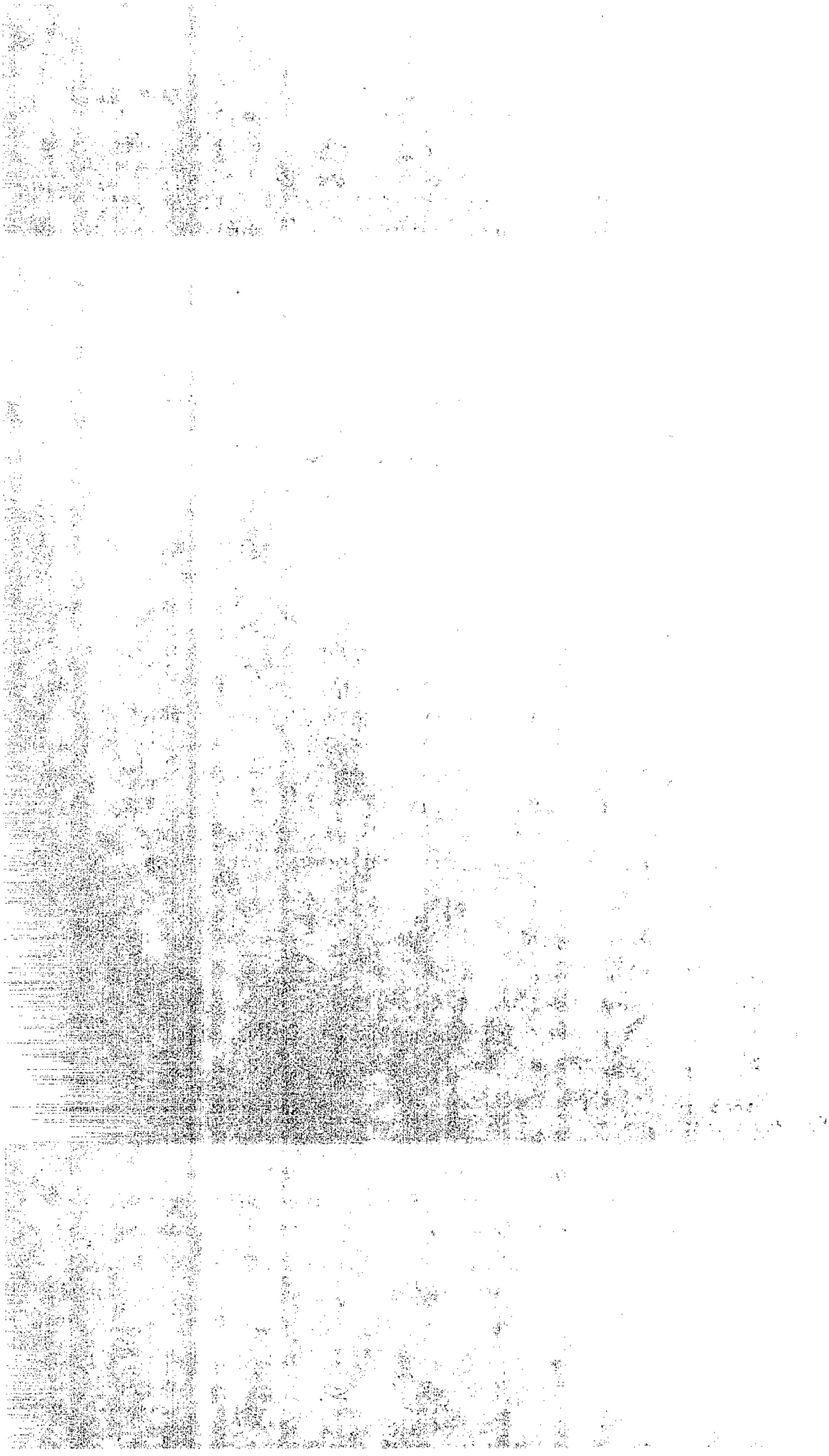
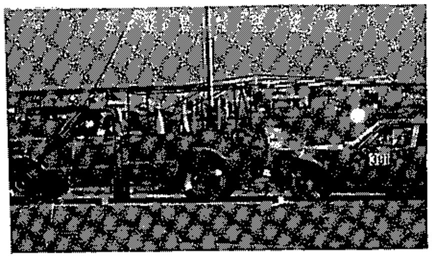
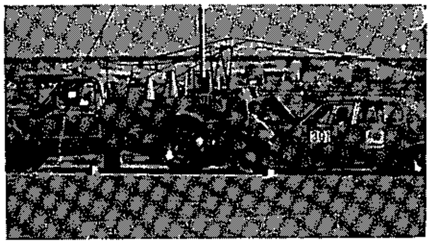


FIGURE 42 - DATA SUMMARY SHEET - TEST 391

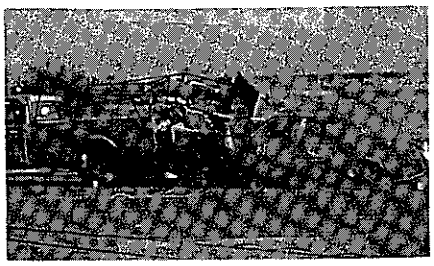


Impact +0.03 Sec.

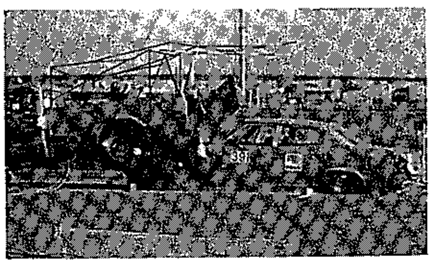


Impact +0.08 Sec.

Impact +0.18 Sec.



Impact +0.28 Sec.



Impact +0.88 Sec.

Test Date	December 1, 1981

Pickup Mounted Attenuator Data

Type	Not Used This Test
Size	Not Used This Test
Weight	Not Used This Test

Pickup Data

Model	1970 Chevrolet, 3/4-T Pickup
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	Neutral
Weight (W/O TMA or Dummy)	4415 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap Belt

Car Data

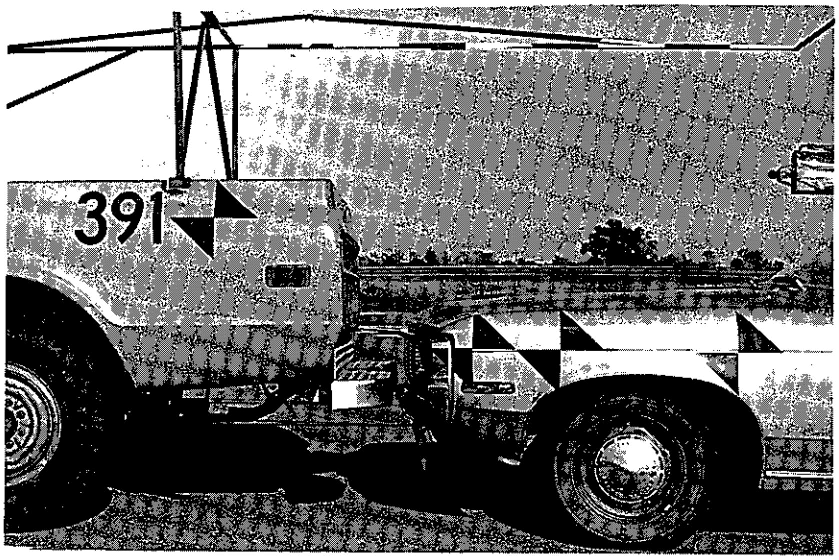
Model	1972 AMC Matador
Impact Velocity	43.9 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	4290 lbs.
Dummy Weight	165 lbs.
Dummy Type	Sierra Stan, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

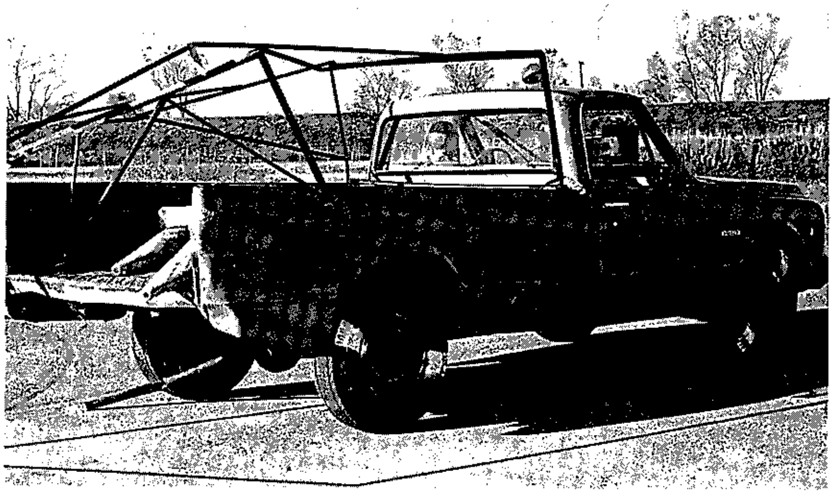
Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal (Film Data)	-8.3 g's
Car, Vertical	No Data
Truck Longitudinal (Film Data)	9.5 g's
Dummy Head, Resultant Truck or Car	No Data
Head Injury Criterion	No Data
Occupant Impact Velocity (Film Data)	28.0 fps
Truck Roll Ahead Distance	
Maximum Pitch, Car (Rear End)	+ & -1.5°
Maximum Rise, Truck Dump Body Rear	18.9 in.
TAD/VDI Index, Car	FD-6/12FDEW5

FIGURE 43

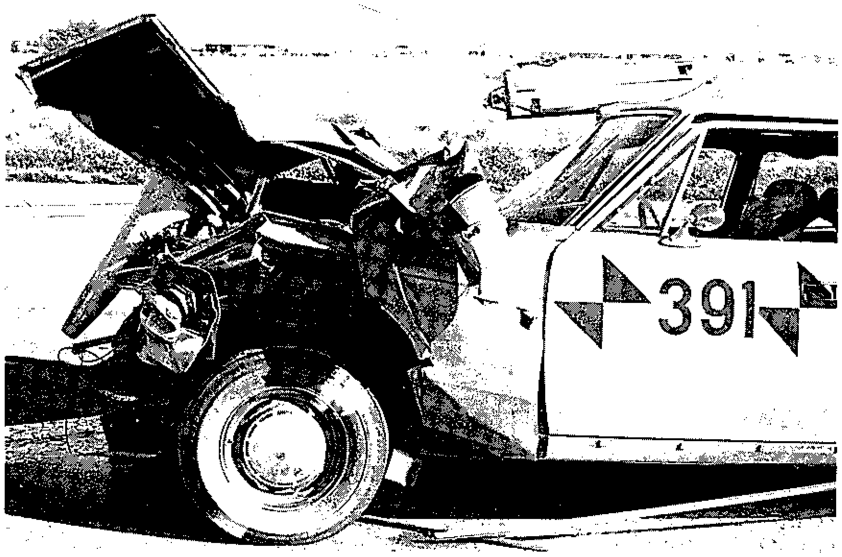
Test 391



Vehicles Before Impact



Pickup After Impact



Car After Impact

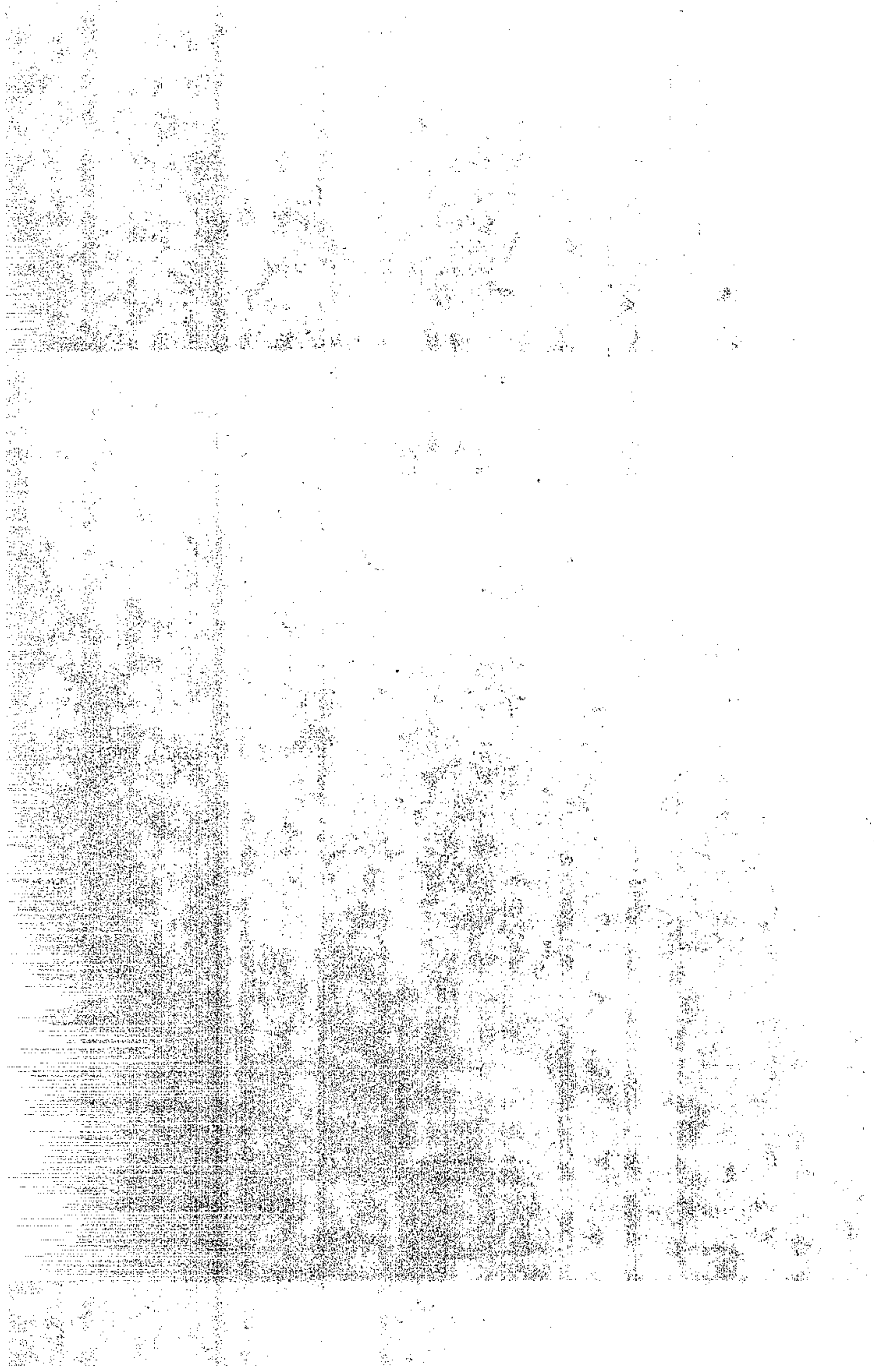
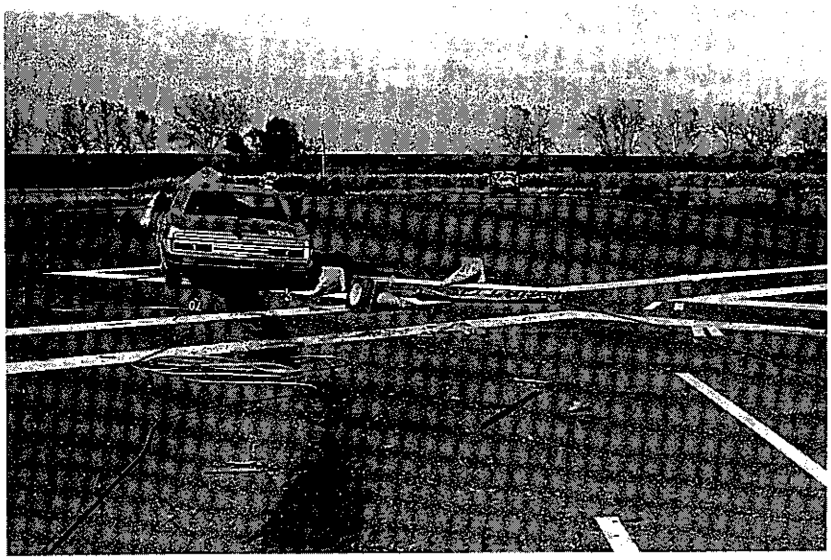


FIGURE 44

Test 391

Car After Impact



Vehicles Final Position

[illegible] CON[illegible]
[illegible] PRODUCT

causing it to move forward. This caused the parking brake tension cables to release and allowed the pickup to roll freely 336-feet. The car rolled ahead 80-feet after impact. There was minimal yawing and pitching of the car during impact. Seven traffic cones placed in the bed of the pickup and the pickup components were scattered around the impact area.

Car Damage - 391: Damage to the car was very severe. All damage was from the rear doors forward to the front of the car. The unitized frame components were buckled below the engine compartment. The radiator was crushed back to the fan. The hood attachments broke loose. The hood impacted and broke the windshield. The front fenders were peeled back 3 to 4 feet. The doors and door posts were not damaged. The underside of the dash was damaged from the dummy's knees. There was some buckling of the floorboards. The car required towing from the impact area.

Truck Damage - 391: The tailgate of the pickup broke free and impacted the car windshield before going over the top of the car and coming to rest on the ground about 40-feet after impact. The rear bumper broke loose upon impact and lodged under the car. The pickup bed was buckled, and crushed about 4-inches. The rear differential was moved forward 2-inches. The battery broke loose and struck the firewall. There was no damage to the interior.

5.3.2 Test - 392

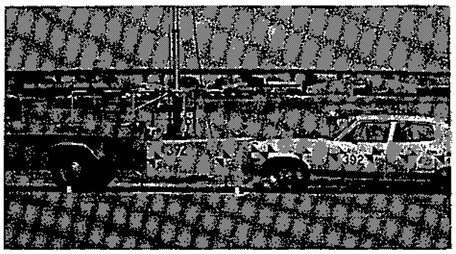
Car - 4310 lbs/45.3 mph/0° Head-On

Pickup - 4140 lbs/5000 lbs. with PMA/Rear Wheels Braked

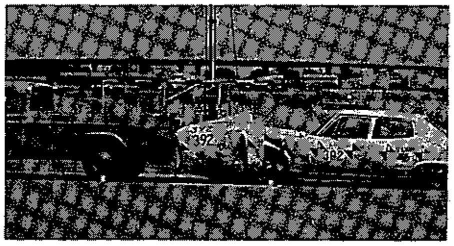
The summary of the test data and photos of the vehicles before and after the impact are shown in Figures 45 - 47.

Impact Description - 392: The car struck the PMA at the intended speed and angle. The car crushed the PMA 59-inches. The front of the car crushed back 7-inches. The car rolled ahead 81-feet, while the truck rolled ahead 80-feet after impact. The pickup came to rest 5-feet to the left of impact center line with the car directly behind. Pitching and yawing of the car were minimal. The impact area was free of debris.

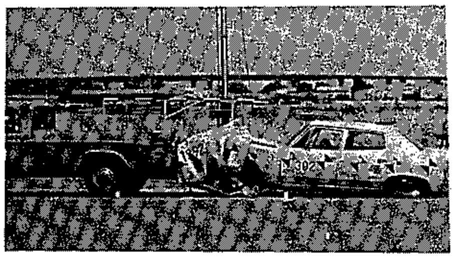
Car Damage - 392: Damage to the car was the least of any TMA or PMA test. The front of the car was only crushed back 7-inches. The front bumper, grill and hood were crushed. The hood remained



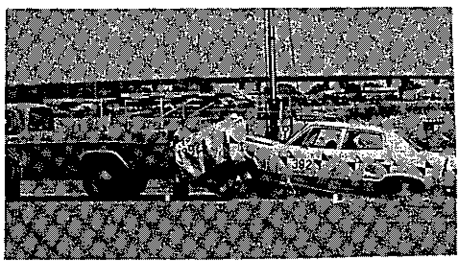
Impact +0.01 Sec.



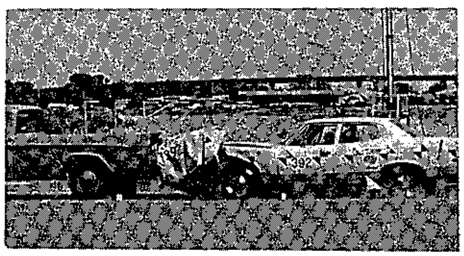
Impact +0.06 Sec.



Impact +0.11 Sec.



Impact +0.21 Sec.



Impact +0.47 Sec.

Test Date	June 9, 1982

Pickup Mounted Attenuator Data

Type	Hexcel Aluminum Honeycomb
Size	5'6" Long x 6'4" Wide 24"High
Weight	200 Lbs., PMA 660 Lbs., Mounting Hardware

Pickup Data

Model	1970 Dodge, 3/4-Ton Pickup
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	Neutral
Weight (W/O TMA or Dummy)	4140 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap Belt

Car Data

Model	1972 AMC Matador
Impact Velocity	45.3 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	4310 lbs.
Dummy Weight	165 lbs.
Dummy Type	Sierra Stan, 50th Percentile
Dummy Restraint	Lap, Shoulder Belts

Impact Data

Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-6.3 g's
Car, Vertical	2.1 g's
Truck Longitudinal	7.7 g's
Dummy Head, Resultant Truck or Car	-17.2 g's
Head Injury Criterion	65
Occupant Impact Velocity (Film Data)	32.9 fps
Truck Roll Ahead Distance	
Maximum Pitch, Car	-4.0°
Maximum Rise, Truck Dump Body Rear	3.5 in.
TAD/VDI Index, Car	FD-4/12FDEW4

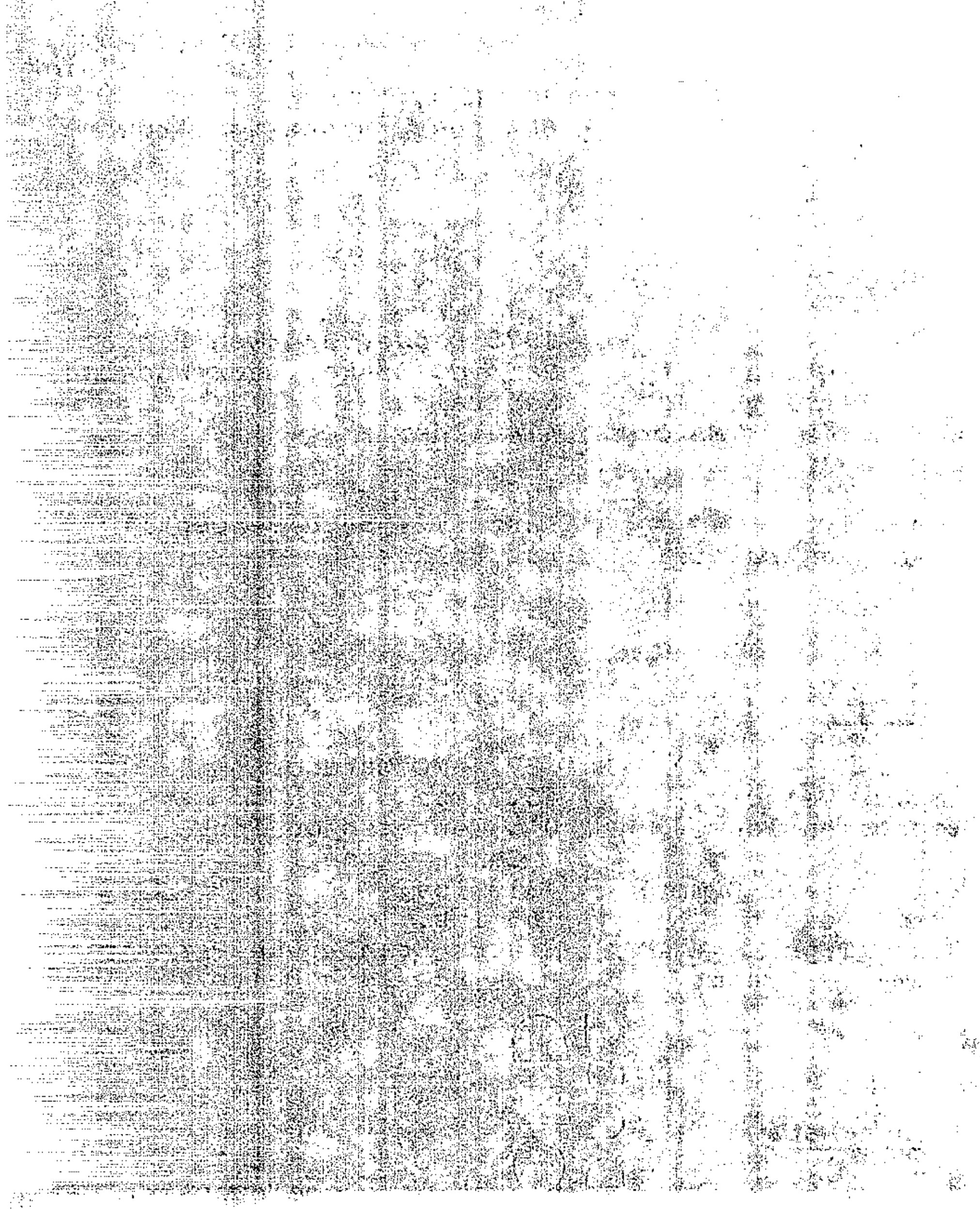
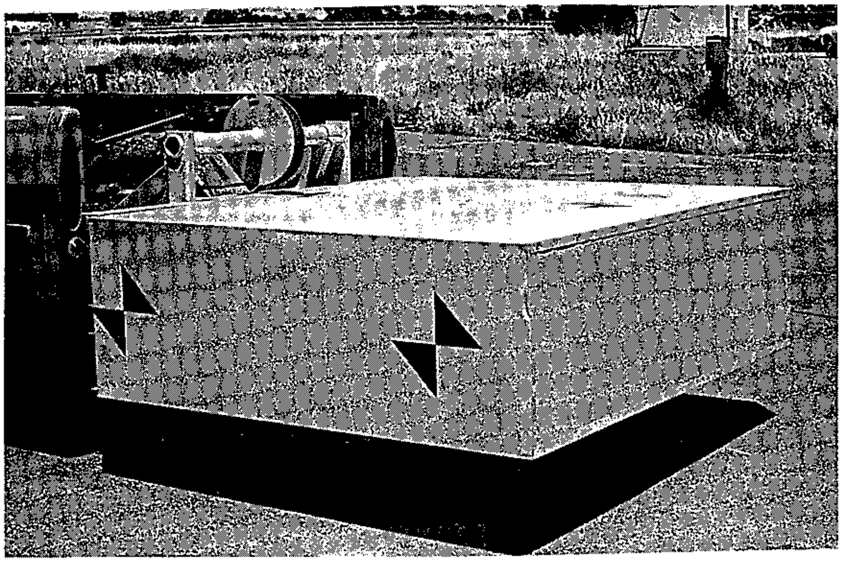
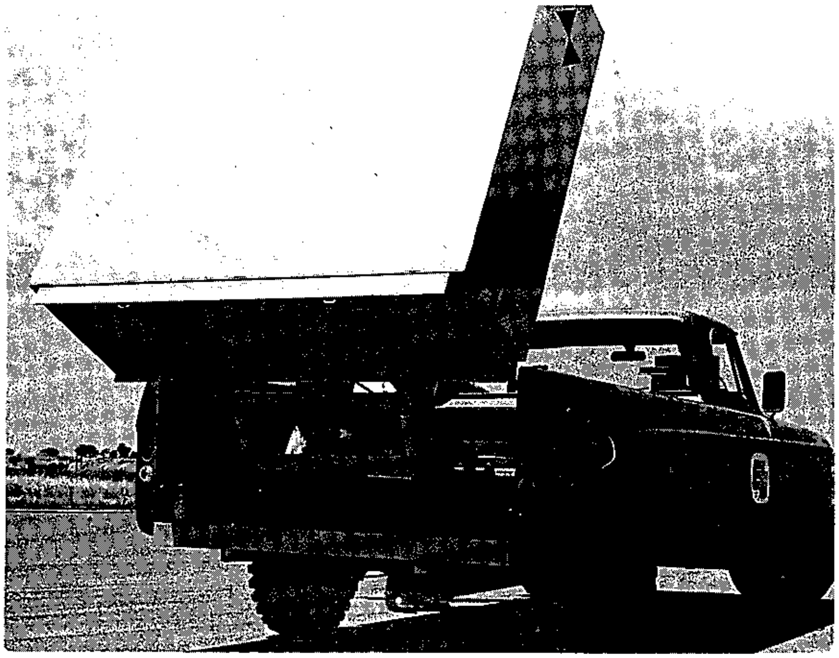


FIGURE 46

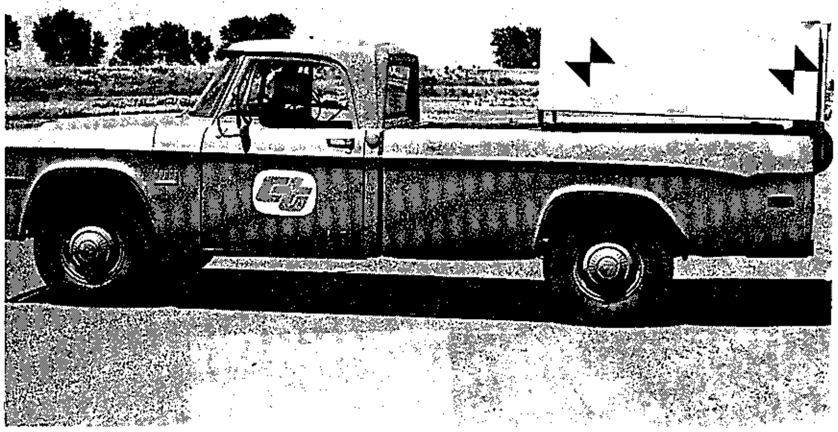
Test 392



Pickup Mounted
Attenuator (PMA)



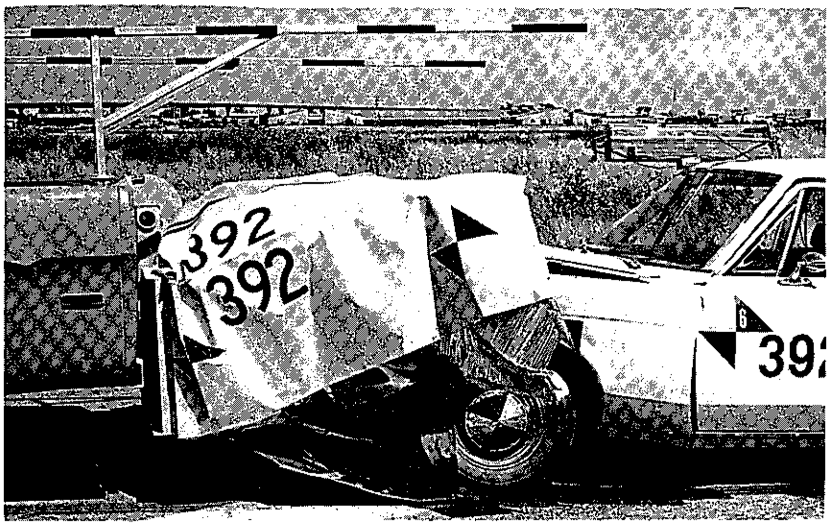
PMA Rotating to
Stored Position



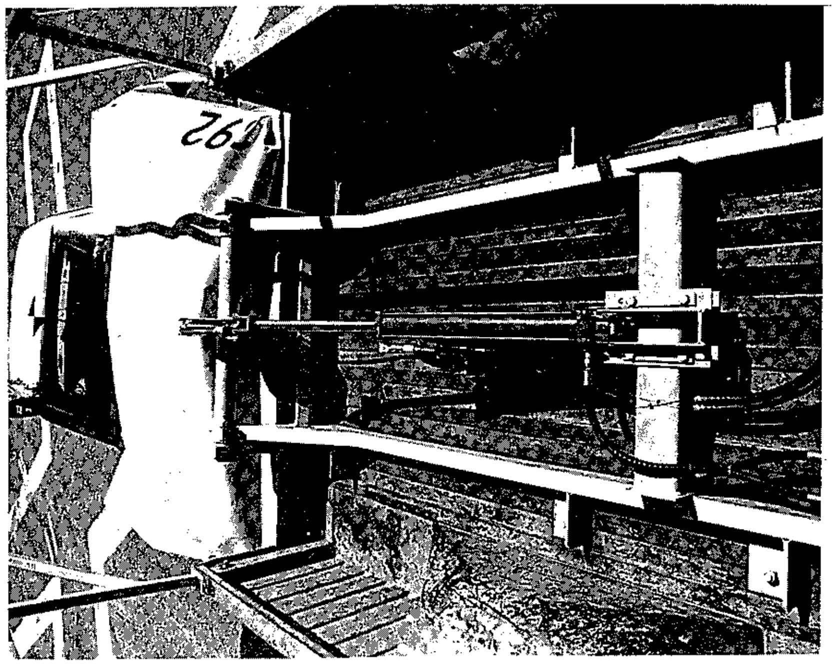
PMA Stored Position

FIGURE 47

Test 392



Vehicles Final Position



PMA Hardware was Undamaged

PMA Crushed 59-Inches
Car Crushed 7-Inches

locked and closed. The radiator was crushed back 4-inches. Engine location was unchanged. Front doors and door posts were not damaged. There was no interior damage. The windshield was intact. The tires were intact. The car was towed from the impact location.

Pickup Damage - 392: There was no pickup damage.

PMA Damage - 392: Ninety percent of the PMA was crushed during impact. The car penetrated the full width of the PMA. There was no damage to the support hardware of the PMA.

5.3.3 Test 393

Car - 1820 lbs/44.8mph/0° Head-On

Pickup - 4140 lbs/5000 lbs W/PMA/Rear Wheels braked

The summary of the test data and photos of the vehicles before and after the impact are shown in Figures 48 - 50.

Impact Description - 393: The car struck the PMA at the intended speed and angle. The car crushed the PMA 42-inches on the bottom and 18-inches on the top side. The car rolled ahead 28-feet while the pickup rolled ahead 25-feet after impact.

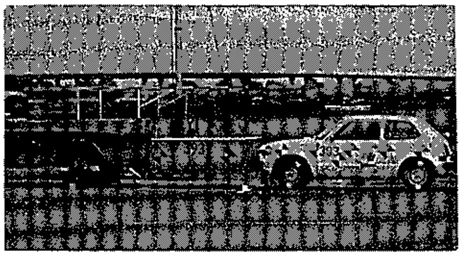
The vehicles came to rest on the impact center line. Pitching and yawing of the car were minimal. The impact area was free of debris.

Car Damage - 393: The front of the car was crushed back 8-inches. The radiator and battery were moved back to the transverse mounted engine. All damage was forward of the front doors. The rear opening hood opened and broke the windshield. The doors were not damaged. In the interior there was minor damage to the dash from the dummy's knees.

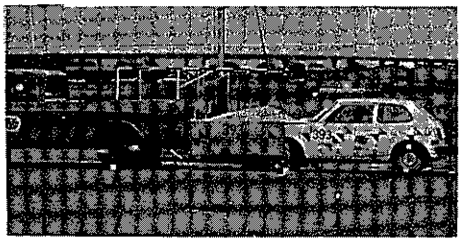
Pickup Damage - 393: There was no pickup damage.

PMA Damage - 393: Forty-five percent of the PMA was crushed during the impact. The car penetrated the center 60-inches of the 76-inch wide of the PMA. There was no damage to the PMA support hardware.

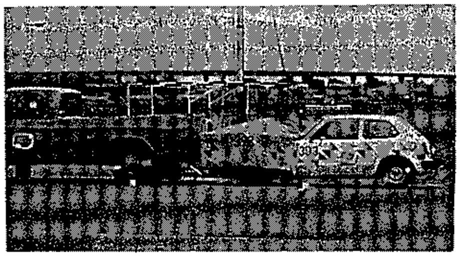
FIGURE 48 - DATA SUMMARY SHEET - TEST 393



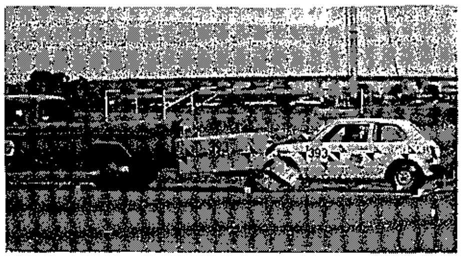
Impact 0.0 Sec.



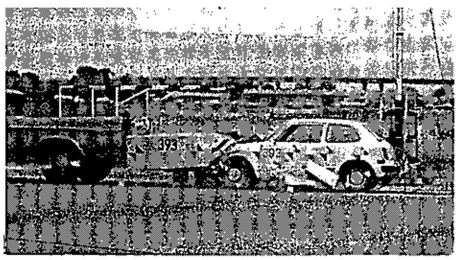
Impact +0.05 Sec.



Impact +0.10 Sec.



Impact +0.58 Sec.



Impact +1.02 Sec.

Test Date September 15, 1982

Pickup Mounted Attenuator Data

Type	Hexcel Aluminum Honeycomb
Size	5'6" Long x 6'4" Wide 24"High
Weight	200 Lbs., PMA 660 Lbs., Mounting Hardware

Truck Data

Model	1970 Dodge, 3/4-Ton Pickup
Brake Setting	Parking Brake, Rear Wheels
Gear Setting	Neutral
Weight (W/O TMA or Dummy)	4140 lbs.
Dummy Weight	165 lbs.
Dummy Type	Part 572, 50th Percentile
Dummy Restraint	Lap Belt

Car Data

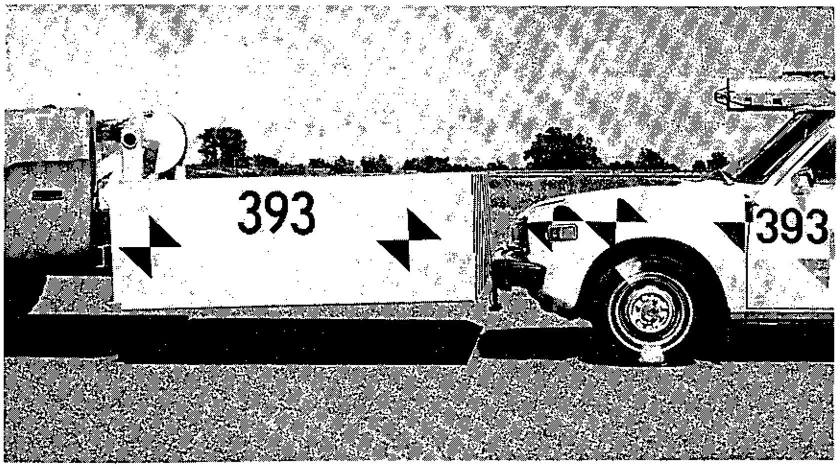
Model	1979 Honda Civic
Impact Velocity	44.8 mph
Impact Angle	0°, Centered on Truck Center Line
Weight (W/O Dummy)	1820 lbs.
Dummy Weight	165 lbs.
Dummy Type	Sierra Stan, 50th Percentile
Dummy Restraint	None

Impact Data

Maximum 50ms. Avg. Acceleration, Accelerometer Data	
Car, Longitudinal	-12.4 g's
Car, Vertical	-1.3 g's
Truck Longitudinal	5.4 g's
Dummy Head, Resultant Truck or Car	-12.4 g's
Head Injury Criterion	28
Occupant Impact Velocity	39.0 fps
Truck Roll Ahead Distance	25 ft.
Maximum Pitch, Car	1.0°
Maximum Rise, Truck Dump Body Rear	3.9 in.
TAD/VDI Index, Car	FD-5/12FDEW4

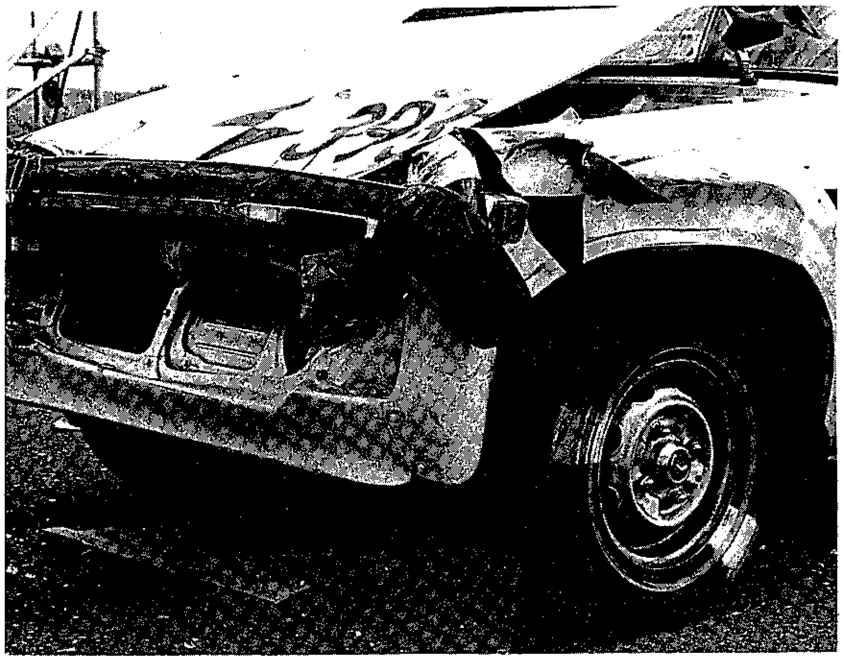
FIGURE 49

Test 393



Vehicles Before Impact

Vehicles Final Positions

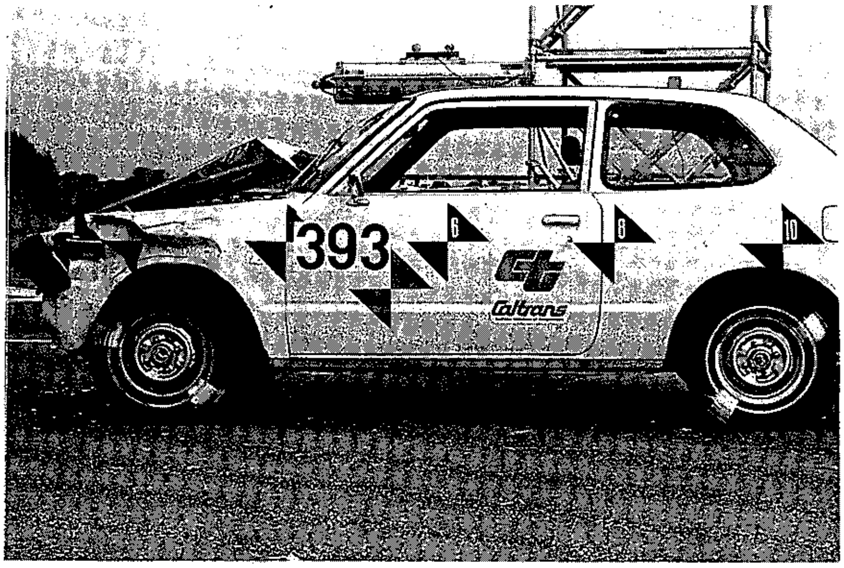


Front of Car Damage

FIGURE 50

Test 393

PMA Crushed 42-Inches



Car Crushed 8-Inches

5.4 Discussion of Test Results

5.4.1 General - Criteria

In TRC No. 191, and National Cooperative Highway Research Program (NCHRP) Report 230, three appraisal factors are recommended for use in judging performance of highway safety appurtenances. These factors can be applied to the results of the TMA tests, although TMAs are not specifically mentioned in this reference. The three factors, which will be discussed below, are (1) structural adequacy, (2) impact severity or occupant risk, and (3) vehicle trajectory.

Table 1 summarizes the data from all twelve tests.

The film report on this project can be used to compare the tests.

5.4.2 Structural Adequacy - Vehicle and TMA Damage

In Table 4 of TRC No. 191 this appraisal factor is described as follows for crash cushions in general:

> "B. The test article shall not pocket or snag the vehicle causing abrupt deceleration or spinout or shall not cause the vehicle to rollover. The vehicle shall remain upright during and after impact although moderate roll and pitching is acceptable. The integrity of passenger compartment must be maintained. There shall be no loose elements, fragments, or other debris that could penetrate the passenger compartment or present undue hazard to other traffic."

> "C. Acceptable test article performance may be by redirection, containment, or controlled penetration by the vehicle."

In Table 6 of NCHRP-230 this appraisal factor is described as follows for highway appurtenances:

> "B. The test article shall readily activate in a predictable manner by breaking away or yielding.

> C. Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle.

ACCELEROMETER DATA

Test No.	CAR Weight (lb.)	CAR Speed (mph)	CAR K.E. (ft.-k)	CAR Momentum (k-Sec.)	CAR Roll Ahead (ft)	CAR Crush (in.)	CAR Occupant Impact Velocity (fps)	CAR Max. 50 ms Avg Accel. (G's)	CAR Max. Angle Change (Deg)* Pitch	CAR Max. Angle Change (Deg)* Yaw	TRUCK/PICKUP 3 Weight (lb.)	TRUCK/PICKUP Braking	TRUCK/PICKUP Roll Ahead (ft)	TRUCK/PICKUP Max. 50 ms Avg Accel. (ft)	TMA PMA Crush (in.)
371	4,315	45	303	9.18	13.9	26.5	46. *	-21.5	-8.0	0	11,600	All	10.3	5.0	No TMA
381	4,260	45.8	299	8.88	36.5	10	31.6	-11.4	-7.0	+2.5	11,970	Rear	29.7	3.6	78
382	4,220	43.9	272	8.44	16.7	12	34.3	-12.1	-3.0 +3.5	-7.0	11,970	Rear	16.7	3.8	62
383	2,085	44.7	139	4.24	10.4	12	42.7	-15.7	+1.0	- .75	11,970	Rear	6.4	3.3	36
384	2,080	43.2	130	4.09	11.5	14	36.8	-15.3	+3.0	Ø	11,970	Rear	6.1	2.7	52
385	2,180	44.4	144	4.41	7.8	12	35.6	-15.2	+2.7	+2.0	11,970	Rear	6.8	2.4	52
386	4,230	45.1	288	8.69	17	11	32.4	-13.6	-3.5	- .75	11,700	Rear	17	4.1	74
387	4,190	45.5	290	8.68	35	14	34.5	-14.4	-	-	11,700	Rear	28	4.3	64
388	4,185	46.4	301	8.84	41	12	33.3	-13.8	-2.5 +4.0	+2.0	11,700	Rear	39.7	4.3	68
389	4,270	44.8	287	8.71	23.2	24 R 0 L	29.1	-10.6	-1.5 +3.75	+2.75	11,700	Rear	14.2	-	66L 36 R
391*	4,290	43.9	276	8.56	80	20	28.0	- 8.3	+1.5 -1.5	-	4,415	Rear	336	9.5	No PMA
392	4,310	45.3	296	8.89	81	7	32.9	- 6.3	-4.0	+2.5	5,000	Rear	80	7.7	59
393	1,820	44.8	122	3.70	28	8	38.9	12.4	+1.0	+4.75	5,000	Rear	25	5.4	18T 42B

NOTES:
1. Car weight does not include weight of dummy.
2. Test 389 angle impact, all other impacts are 0°.
3. Includes weight of TMA or PMA

* Data obtained from film.

TABLE 1

D. Detached elements, fragments or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic."

Integrity of Car Passenger Compartment and Damage to Car

There was no intrusion of vehicle or attenuator parts into the passenger compartment in Tests 381-389 when using the TMA and 391-393 when using the PMA. In Test 389, the angle impact test, there was some minor intrusion on the right front side of the passenger compartment. In Test 371 there was no TMA on the truck. The dashboard and steering column of the car were pushed in a short distance into the passenger compartment. In addition, the hood barely punched through the windshield. There was some buckling of the floorboard.

In Test 391 there was no PMA on the pickup. The front end crush of the car was 18.0 inches. In addition the windshield was penetrated by the hood causing severe shattering of the windshield.

Although the windshield cracked only in one test, it did not appear to be a threat to passengers. There was no damage to the dummy in Test 371 or 391. The other tests clearly showed there was better protection of the passenger compartment with a TMA mounted on the truck or a PMA mounted on a pickup. This difference probably would be even more evident at impact speeds over 45 mph.

One measure of car damage is the amount of crush to the front end. It is difficult to compare the vehicle crush in different tests because different model cars were used with different front end components, each having different crush resistances. Even when same model cars were used, slight differences in the vehicle kinematics could affect the final crush profile. The method used to compare crush was by length of crush to the front of the car. The values for all tests are shown in Table 1. The crush profile values were all quite uniform, between 7 and 14 inches, for the head-on tests at 45 mph except for baseline Tests 371 and 391. In Test 371 where no TMA was used, the crush was 26.5 inches which shows dramtically the usefulness of the TMA. In Test 391 where no

PMA was used, the crush was 18-inches. This also illustrates the effectiveness of the PMA. The penetration was basically a uniform profile on all the impacting test vehicles. Although the crush values were similar in the 45 mph/head-on impacts for both large and small cars, the value of crush in a small car represents a more severe impact than for a large car as is evidenced by the larger values of acceleration, Table 1. The car crush profile for angle Test 389 was zero crush on the left side and 24 inches on the other.

The VDI(7) and TAD(8) car damage scales are given on the Data Summary Sheets for each test. They also show the amount of car damage was similar for all tests except Test 371 where damage was much more severe.

<u>Damage to TMA and PMA</u>

In Tests with the large cars, virtually all cells in the TMA and PMA were crushed uniformly. In tests with the smaller cars, all of the back sections of cells were not crushed or were only slightly crushed. Hence, the tests show the TMA and PMA were designed close to the ideal stiffness for large cars at 45 mph because all the crush distance available in the TMA and PMA was used up.

Data from the test movies show the maximum dynamic penetration of the cars during impact. The penetration represents the dynamic crush of the TMA and PMA and car front end:

Test No.	Maximum Dynamic Penetration of Car	
371	4.8 ft.	Base Line No TMA
381	7.3	
382	6.2	
383	4.0	
384	5.5	
385	5.3	
386	7.1	
387	6.5	
388	6.7	
389	6.3 Avg.	
391	1.7	Base Line No PMA
392	5.5	
393	3.2	

Most of this penetration occurred before the truck had moved ahead more than a few inches.

Penetration in Test 371 and 391 was relatively less because there were no attenuators. The penetration includes the distance the car nosed under the truck and the crush of the car.

In all tests with the TMA or PMA there was no damage to the steel backup frame and controls with the following exceptions. There was light damage in Test 389. The frame bent one-inch due to the 10 degree angle of the impact.

Car and Truck Kinematics

There was no loss of control or stability to the truck or car during the tests. There was excessive roll ahead of the pickup during the base line test. The car submarined and struck the truck differential causing the parking brake to release. The pitch, roll and yaw of the cars were minimal. Values of pitch and yaw are given in Table 1. The TMA and PMA controlled the acceleration of the car in all tests. Even in Test 389, the offset angular impact, it was surmised the car might spinout; instead it came to rest close behind the truck.

5.4.3 Impact Severity or Occupant Risk: TMA Cushioning Effectivness

The guidelines for highway crash cushions in Table 4 of TRC No. 191 are as follows:

> "C. For direct-on impacts of test article, where vehicle is decelerated to a stop and where lateral accelerations are minimum, the preferred maximum vehicle acceleration average is 6 to 8 g's and the maximum average permissible vehicle deceleration is 12 g's as calculated from vehicle impact speed and passenger compartment stopping distance."

In Table 6 of NCHRP-230 this appraisal factor is described as follows:

> "E. The vehicle shall remain upright during and after collision although moderate roll, pitching and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.

F. Impact velocity of hypothetical front seat passenger against vehicle interior, calculated from vehicle accelerations and 24 inches (0.61m) forward and 12 inches (0.30m) lateral displacements, shall be less than:

Occupant Impact Velocity - fps	
Longitudinal	Lateral
$40/F_1$	$30/F_2$

and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than:

Occupant Ridedown Accelerations - g's	
Longitudinal	Lateral
$20/F_3$	$20/F_4$

where F_1, F_2, F_3, and F_4 are appropriate acceptance factors (See Table 8, Chapter 4 for suggested values).

These criteria will be used to evaluate the TMA and PMA.

Car Accelerations

Car accelerations were computed and are in Table 1. The highest 50ms average value from the accelerometer data used in Table 1 was compared with film data. It was determined the accelerometer data was more conservative. As shown on Table 1, Test 371 without a TMA was -21.5 g's. This is considerably above the limit of -12 g's. In the heavy car TMA tests the accelerations ranged from -10.7 to -13.8 g's and in the lightweight car tests -15.7 to -15.2 g's. Some are above the -12 g limit, but these figures do highlight the difference of severity with and without a TMA. It should be noted that an impact of a lightweight car without a TMA would result in accelerations of -25 to -30 g's.

In the PMA baseline Test 391 data was lost due to an electronic malfunction. The figures, as shown in Table 1 of -6.3 g's (heavy car) and -12.4 g's (lightweight car), indicate the PMA performed well.

Truck Acceleration

Rear end impacts not only decelerate the car, but force the truck to accelerate rapidly. Table 1 gives truck cab accelerations which vary from a maximum of 5.0 g's in Test 371, the control test without a TMA, down to 2.4 g's in Test 385, the lightweight car impact with a TMA (based on accelerometer data).

Table 1 gives the pickup cab accelerations which vary from a maximum of 9.5 g's in Test 391, the control test without a PMA, down to 5.4 g's in Test 393. These values are well below those of the car accelerations.

Even though the accelerations are relatively low, they may still cause whiplash or other head injuries to truck drivers or passengers. The Division of Equipment Maintenance and Development has implemented a program to install head restraints in all vehicles with TMAs to minimize the effects of truck accelerations in rear end impacts.

Dummy Accelerations

Accelerometers in the head of the dummy in the impacting passenger cars measured acceleration in three directions. They show very high accelerations of about 40 g's in Test 371 of the control test. In the final TMA design for a lightweight car impact, the dummy accleration was 18.7 g's (Test 385) and 15.0 g's for a heavy car (Test 388). These data indicate that the TMA helped to reduce dummy accelerations, and the use of a shoulder belt is important, particularly in lightweight and miniweight cars.

Accelerometers were in the head of the dummy in the impacted pickup truck in the PMA tests (391 - 393). This was done to determine the severity of head accelerations to which a driver of the pickup would be subjected. The dummy accelerations were 12.4 g's for the lightweight car (Test 393) and 17.1 g's for a heavy car (Test 392).

Evaluation criteria of longitudinal occupant impact velocity (fps) was also used to judge the performance of the TMA and PMA.

The longitudinal occupant impact velocity is theoretical; however, on the plot of distance vs time, the curves can be visualized as representing the car windshield and the driver's head. It is assumed that the head starts out two feet behind the windshield. The point where the curves cross represents the impact between the head and the windshield because the windshield has slowed down from the impact velocity, but the head has not. The time when the windshield/head impact occurs (rattlespace time) is carried to the plot of velocity vs time. The occupant impact velocity is the difference between the vehicle impact velocity and the vehicle velocity at the end of the rattlespace time. (The dummy accelerometers are not used in determining the occupant impact velocity, only the vehicle accelerometers.)

The longitudinal occupant impact velocity was obtained from accelerometer data through the use of the wave form analyser. Following is a table of longitudinal occupant impact velocities which are all below the limit of 40fps in Table 6 of NCHRP-230 except for the baseline Test 371 and Test 383. Table 8 in the Commentary of NCHRP-230 recommends occupant impact velocities in the longitudinal direction of 30 fps. Therefore, impacts at speeds over 45 mph would be moving quickly out of the range of acceptable performance unless the truck was moving at the time of impact.

Test No.	Longitudinal Occupant Impact Velocity (FPS)		
371 No TMA	46	Heavy Car	Head-On
381 W/TMA	31.6	Heavy Car	Head-On
382 W/TMA	34.3	Heavy Car	Head-On
383 W/TMA	42.7	Lightweight Car	Head-On
384 W/TMA	36.8	Lightweight Car	Head-On
385 W/TMA	35.6	Lightweight Car	Head-On
386 W/TMA	32.4	Heavy Car	Head-On
387 W/TMA	34.5	Heavy Car	Head-On
388 W/TMA	33.3	Heavy Car	Head-On
389 W/TMA	29.1	Heavy Car	10° Angle
391 No PMA	28	Heavy Car	Head-On
392 W/PMA	32.9	Heavy Car	Head-On
393 W/PMA	38.9	Lightweight Car	Head-On

These data were used to determine the TMA used in Tests 385, 388 and 389 provide the best performance of heavy, lightweight, and angle impacts and would be the final acceptable TMA design.

NCHRP-230 states, "Whereas the highway engineer is ultimately concerned with safety of the vehicle occupants, the occupant risk criteria (vehicle and dummy accelerations and occupant impact velocities) should be considered as the guidelines for generally acceptable dynamic performance. These criteria are not valid, however, for use in predicting occupant injury in real or hypothetical accidents". The Commentary in NCHRP-230 adds, "The relationship between occupant safety and vehicle dynamics during interaction with a highway appurtenance is tenuous because it involves such important, but widely varying factors as occupant physiology, size, seating position, attitude, and restraint, and vehicle interior geometry and padding".

5.4.4 Vehicle Trajectory

Guidelines from Table 4 of TRC No. 191 are:

> "A. After impact, the vehicle trajectory and final stopping position shall intrude a minimum distance into adjacent traffic lanes."
>
> The accompanying test states:
>
> "A subjective apprasial shall be made by the test engineer as to the trajectory hazard, based on vehicle exit speed and angle, maximum intrusion into a traffic lane or lanes during trajectory, and post crash controllability."

In Table 6 of NCHRP 230 the guidelines are:

> "H. After impact the vehicle trajectory and final stopping position shall intrude a minimum distance into adjacent traffic lanes."
>
> "J. Vehicle trajectory behind the test article is acceptable."

These guidelines will be used to evaluate the TMA and PMA.

Effect on Adjacent Traffic Lanes

In all TMA tests, except Test 389, the car and truck traveled a short distance in a straight line. The car stayed directly behind the truck. Therefore, the effect on adjacent traffic would have been minimal. Even in Test 389, the offset angular impact, the car stayed close to the rear of the truck and would have minimal affect on adjacent traffic lanes.

In the baseline PMA test, with no attenuator, it was clearly demonstrated how an impact on a parked vehicle could cause additional collisions. The pickup rolled over 300 ft. uncontrollably. The data from this test will be used by Caltrans to demonstrate to various operational sections the care they must use when parking their pickups on and along roadways.

The baseline PMA test also demonstrated the value of an attenuator. In PMA tests 392 and 393 with PMAs, the impacts were controlled and predictable. The effect on adjacent lanes would have been minimal.

It should be noted that the PMA was designed for slow moving operations and not for parking to protect a stationary work location.

An overall apprasial is that when TMAs and PMAs are used, the impacts are controlled and predictable. They reduce the hazards of work locations and those of traffic substantially.

6. REFERENCES

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2. Jung, F. W., "Design of Barrel Trailer for Maximum Collison Protection", Transportation Research Board, Transportation Research Record No. 631, 1977, pp 76-81.

3. Carney, J. F., III, "Experimental Evaluation of a Portable Energy Absorbing System for Highway Service Vehicles, Final Report for Phase I", University of Connecticut, January 1977.

4. Stoughton, R. L., J. R. Stoker, E. F. Nordlin and J. Roberts, "Vehicle Impact Tests of a Truck Mounted Attenuator Containing Vermiculite Concrete Cells", California Department of Transportation, Transportation Laboratory, June 1980.

5. "Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances", Transportation Research Circular No. 191, February 1978.

6. "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances", National Cooperative Highway Research Program Report 230", March 1981.

7. "Collision Deformation Classification, Recommended Practice J224a", 1973 Handbook, Society of Automotive Engineers, New York, 1973.

8. "Vehicle Damage Scale for Traffic Accident Investigators", Traffic Accident Data Project Bulletin No. 1, National Safety Council, 1968.

APPENDIX A: TEST VEHICLE EQUIPMENT AND GUIDANCE METHODS

- Two 12-volt wet cell lead acid motorcycle-type batteries were mounted in the truck to supply power for the test equipment in the car.

- The test vehicle gas tank was disconnected from the fuel supply line and drained. In Tests 381, 382, 386-389, 391, and 392 the tank was filled with water to add weight to the car and eliminate the fire hazard. In Tests 383-385 and 393, extra weight was not needed, so dry ice was placed in the empty tank to inhibit combustion. A one-gallon safety gas tank was installed in the trunk compartment and connected to the fuel supply line.

- The accelerator pedal was linked to a small cylinder with a piston which opened the throttle. The piston was activated by a manually thrown switch mounted on the top of the rear fender of the test vehicle. The piston was connected to the same CO_2 tube used for the brake system, but a separate regulator was used to control the pressure. The car was placed in second gear.

- A speed control device connected between the negative side of the coil and the battery of the vehicle regulated the speed of the test vehicle based on speedometer cable output. This device was calibrated prior to the test by conducting a series of trial runs through a speed trap composed of two tape switches set a known distance apart connected to a digital timer.

- A cable guidance system was used to direct the vehicle into the barrier. The guidance cable, anchored at each end of the vehicle path to a threaded coupler embedded in a concrete footing, passed through a guide bracket bolted to the spindle of the right front wheel of the vehicle. A steel knockoff bracket, anchoring the end of the cable closest to the barrier to a concrete footing, projected high enough to knock off the guide bracket, thereby releasing the vehicle from the guidance cable prior to impact.

- A micro switch was mounted below the front bumper and connected to the ignition system. A trip plate placed on the ground near impact triggered the switch when the car passed over it. This opened the ignition circuit, cut the vehicle engine prior to impact, and released the sliding weight from an electro-magnet so the weight was free to travel slightly before the instant of impact.

- A solenoid-valve actuated CO_2 system was used for remote braking after impact or for emergency braking any other time. Part of this system was a cylinder with a piston, which was attached to the brake pedal. The pressure used to operate the piston was regulated according to the test vehicle's weight, to stop the test vehicle without locking up the wheels.

- The remote brakes were controlled at the console trailer by using an instrumentation cable connected between the vehicle and the electronic instrumentation trailer, and a cable from that trailer to the console trailer. Any loss of continuity in these cables caused an automatic activation of the brakes and ignition cutoff. Remote activation of the brakes also would turn off the ignition.

APPENDIX B: PHOTO-INSTRUMENTATION

Data film was obtained by using five high speed Photo-Sonics Model 16 mm-1B cameras, 200-400 frames per second (fps), and four high speed Redlake Locam cameras, 400 fps. These cameras were located around the impact area as shown in Figure B1. The cameras were electrically actuated from a central control console located adjacent to the impact area, except for three which had their own battery power and were turned on by three separate operators.

All high speed cameras were equipped with timing light generators which exposed reddish timing pips on the film at a rate of 1,000 per second. The pips were used to determine camera frame rates and to establish time-sequence relationships. Data from the high-speed movies were reduced on a Vanguard Analyzer. Some procedures used to facilitate data reduction for the test are listed as follows:

1. Butterfly targets were attached to the test car, truck, pickup, and TMA. Figures B2, B3, and B4 show the target location dimensions.

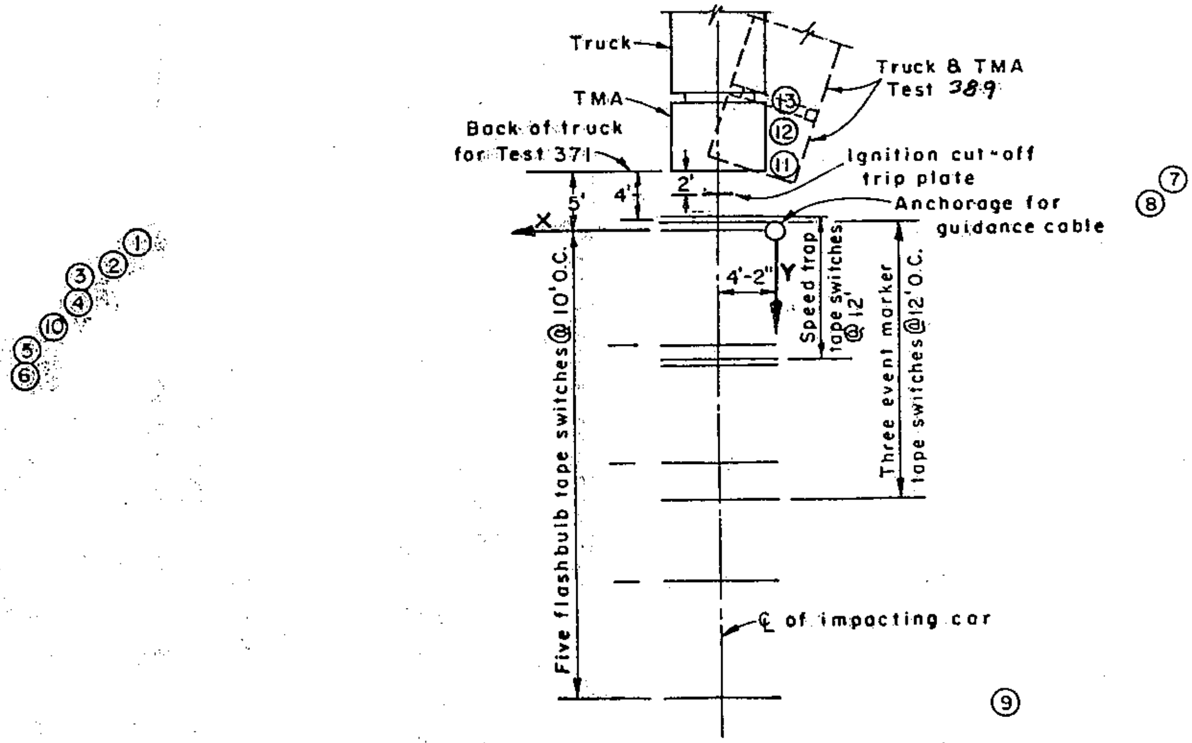
2. Flashbulbs, mounted on the test vehicle, were electronically flashed to establish (a) initial vehicle/barrier contact (b) application of the vehicle's brakes and (c) beginning and ending of sliding weight travel. The impact flashbulbs have a delay of several milliseconds before lighting up.

3. Five tape switches, placed at ten foot intervals, were attached to the ground perpendicular to the path of the impacting vehicle beginning about five feet from impact. Flashbulbs were activated sequentially when the tires of the test vehicle rolled over the tape switches. The flashbulb stand was placed in view of most of the data cameras or made visible to the tower cameras through the use of mirrors. The flashing bulbs were used to correlate the cameras with the impact events and to calculate the impact speed independent of the electronic speed trap.

Additional coverage of the impacts was obtained by a 70 mm Hulcher sequence camera and a 35 mm Hulcher sequence camera (both operating at 20 frames per second). Documentary coverage of the tests consisted of normal speed movies and still photographs taken before, during and after the impact.

A sliding weight device was mounted on all test cars to determine the rattlespace time as defined in Section 5.4.3. This device would only be used if accelerometer data failed. The weight contains ball bearings which roll along a smooth rod. The weight is held in place on the left end of the rod by an electronmagnet before impact. The front bumper switch on the car which cuts the ignition about two feet before impact also cuts off the current to the electromagnet. The weight is then free to slide forward for a two foot distance on the rod after impact. The time it takes for the weight to travel two feet (rattlespace time) is determined from the high speed movie film. Flash bulbs mounted on the device are activated when the weight begins to move and also when it reaches the end of its travel. The flashbulbs are more visible to distant data cameras than the sliding weight.

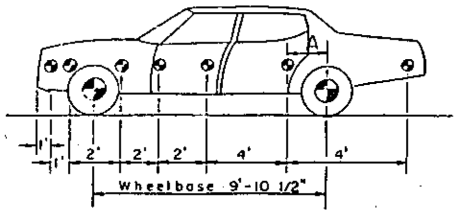
Figure B1 , CAMERA AND TAPESWITCH LAYOUT



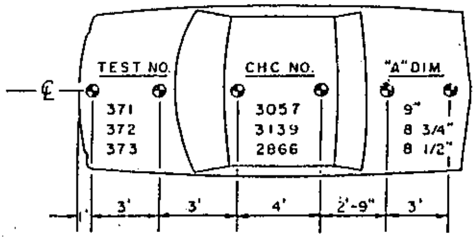
CAMERA DATA

No.	Coord. (ft) x	Coord. (ft) y	Type	Lens	Speed (Frames/ sec)	Mounting
1	82	1	Redlake Locam 16mm	50mm	400	Tripod
2	96	3	Redlake Locam 16mm	25mm	400	Tripod
3	100	4	Redlake Locam 16mm	38mm	400	Tripod-Pan
4	100	4	Bolex 16mm	18mm	24	Tripod-Pan
5	115	15	Hulcher 70mm	150mm	20	Tripod
6	115	15	Hulcher 35mm	105mm	20	Tripod
7	- 82	- 6	Photo-Sonics 16mm-1B	13mm	350	Tripod
8	- 76	- 2	Redlake Locam 16mm	50mm	400	Tripod
9	- 27	192	Photo-Sonics 16mm-1B	4 in.	200	Tripod
10	108	8	Videotape	-	-	Tripod
11	0	- 11	Photo-Sonics 16mm-1B	13mm	400	Tower
12	0	- 11	Photo-Sonics 16mm-1B	13mm	400	Tower
13	0	- 11	Photo-Sonics 16mm-1B	13mm	400	Tower

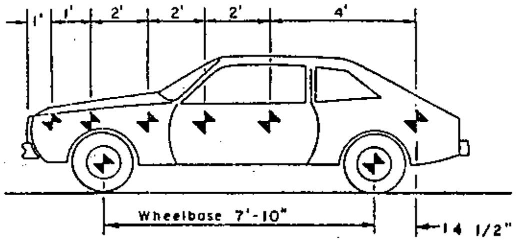
FIGURE B2, TEST CAR TARGETING AND DIMENSIONIONS



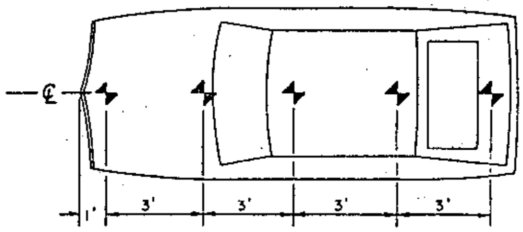
1971 AMC MATADOR SEDAN



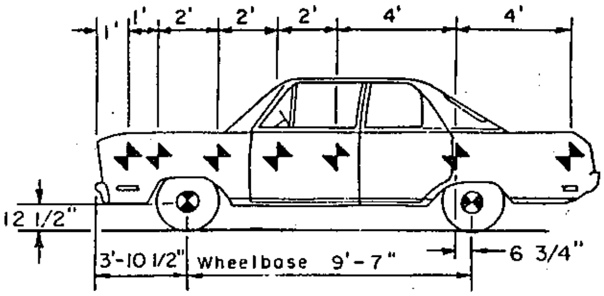
TESTS 371,382,386-388



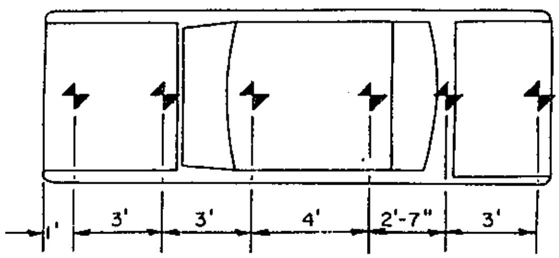
1972 FORD PINTO COUPE



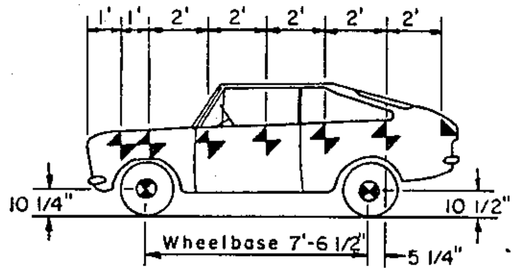
TEST 385



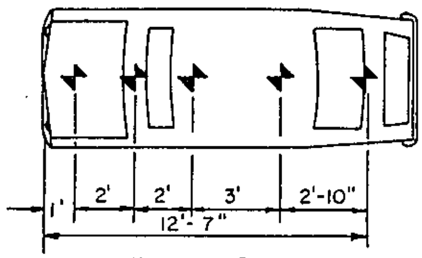
1970 PLYMOUTH BELVEDERE SEDAN



TEST 381 & 389



1974-76 TOYOTA COUPE

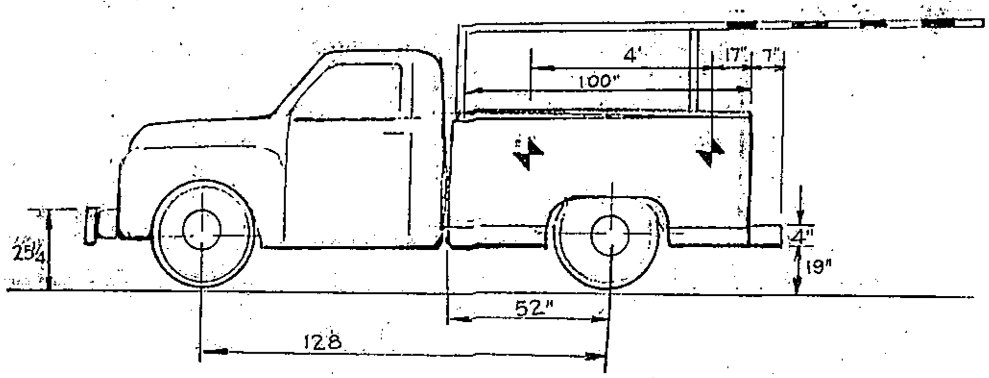


TEST 383 & 384

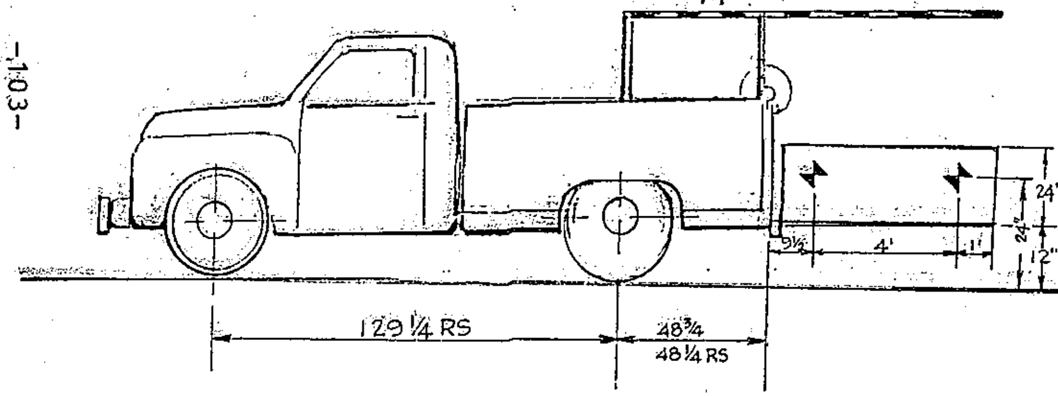
Note:
Drawings not to scale

FIGURE B3, TEST PICKUP AND CAR TARGETING

Test 391



12" Typ

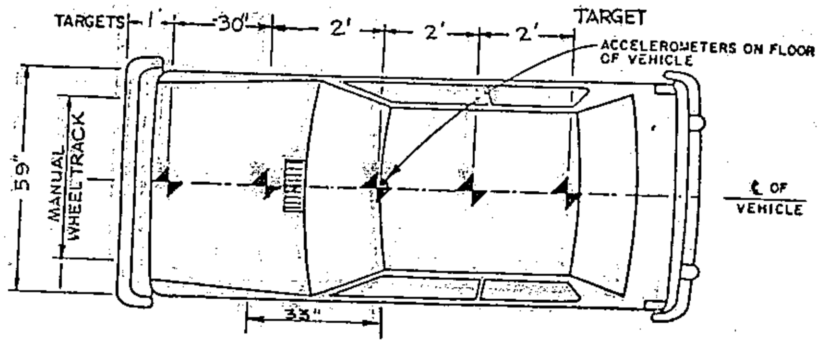


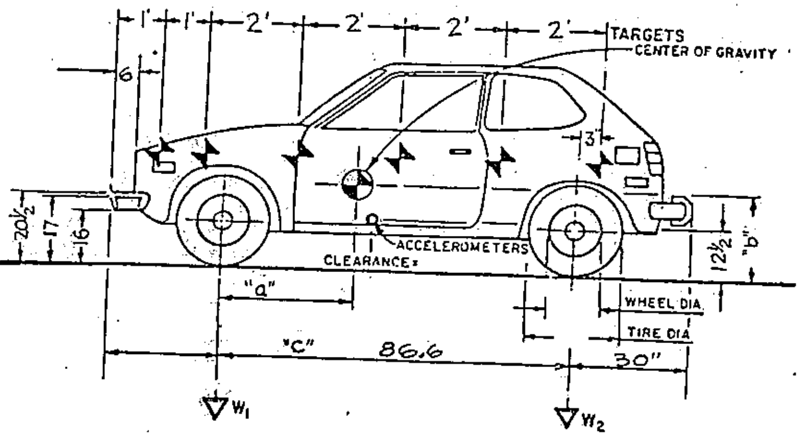
Test 392 & 393

Test 393

TEST NO.
VEHICLE —

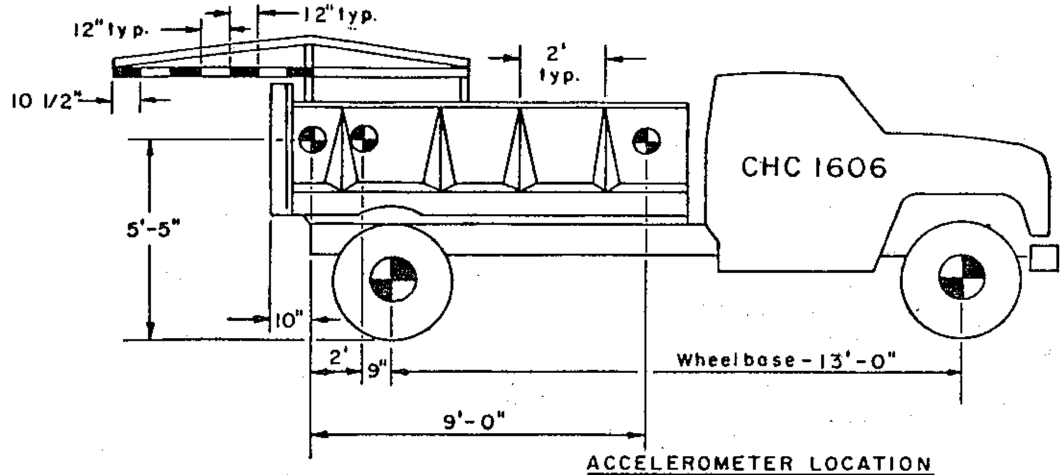
TEST DATE—





Test 393

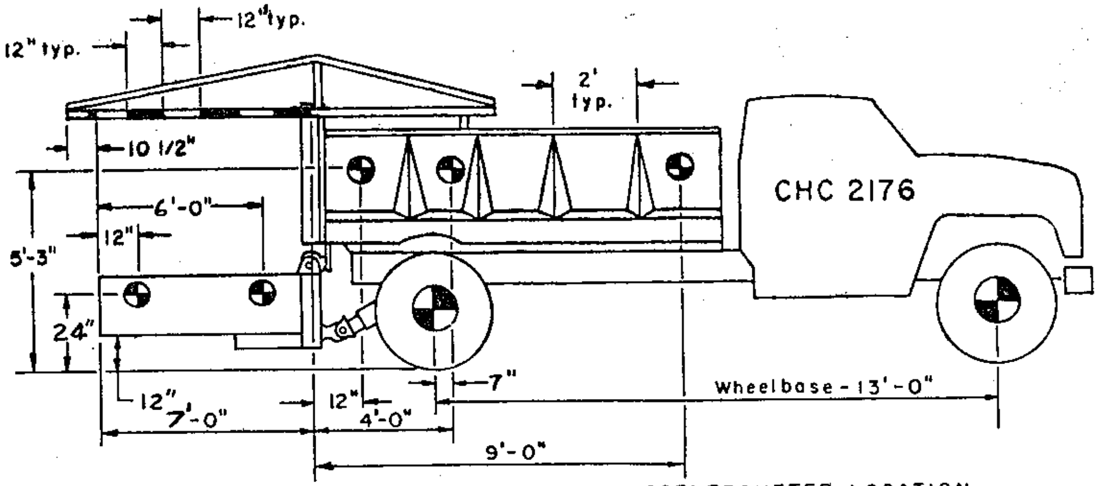
Figure B4, TRUCK TARGETING AND DIMENSIONS



ACCELEROMETER LOCATION

120" Forward of rear axle on passenger compartment floor near left door jamb.

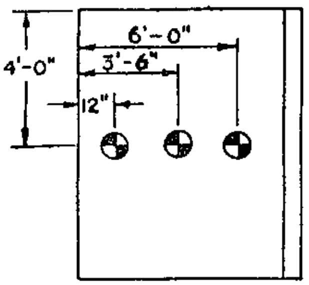
TEST 371



ACCELEROMETER LOCATION

120" Forward of rear axle on passenger compartment floor near left door jamb.

TEST 381-389



ATTENUATOR TOP VIEW

Truck Data - All Tests

Ford F-750
Four cu. yd. dump body
Rated Gross Vehicle Wt. = 25,000 lb.
Truck Wt. = 11,600 lbs - Test 371
W/TMA 11,970 lbs - Tests 381-385
11,700 lbs - Test 386-389

All drawings not to scale

APPENDIX C: ELECTRONIC INSTRUMENTATION AND DATA

Three Endevo Model 2262-200 piezo-resistive accelerometers were mounted in the head of the dummy. Statham unbonded strain gage type accelerometers were mounted on steel angle brackets which were welded to the floor of the cars and trucks. Those in the car were close to the center of gravity in the horizontal plane; those in the truck were on the left edge of the cab where they received solid support from the truck frame. The dummy accelerometers were mounted inside the head cavity.

Data from the accelerometers in the test vehicle were transmitted through a 1,000 foot Belden #8776 umbilical cable connecting the vehicle to a 14-channel Hewlett Packard 3924C magnetic tape recording system. This recording system was in an instrumentation trailer at the test control area.

Three pressure-activated tape switches were placed on the ground in front of the test barrier. They were spaced at carefully measured intervals of 12 feet. When the test vehicle tires passed over them, the switches produced sequential impulses or "event blips" which were recorded concurrently with the accelerometer signals on the tape recorder and served as "event markers". A tape switch on the front bumper of the car closed at the instant of impact and activated flash bulbs mounted on the car. The closure of the bumper switch also put a "blip" or "event marker" on the recording tape. A time cyle was recorded continuously on the tape with a frequency of 500 cycles per second. The impact velocity of the vehicle could be determined from the tape switch impluses and timing cycles. Two other tape switches connected to digital readout equipment were placed 12 feet apart just upstream from the test barrier specifically to determine the impact speed of the test vehicle immediately after the test. The tape switch layouts are shown in Appendix B in Bigure B1.

All accelerometer data were processed on a Norland Model 3001 waveform analyzer which was the primary means of data reduction. The analyzer digitized and manipulated the raw data, printed test results, and plotted various curves. These data curves are shown in Figures C1 through C43.

The occupant impact velocity is theoretical; however, on the plot of distance vs time, the curves can be visualized as represening the car windshield and the driver's head. It is assumed that the head starts out two feet behind the windshield. The point where the curves cross represents the impact between the head and the windshield because the windshield has slowed down from the impact velocity, but the head has not. The time when the windshield/head impact occurs (rattlespace time) is carried to the plot of velocity vs time. The occupant impact velocity is the difference between the vehicle impact velocity and the vehicle velocity at the end of the rattlespace time.

(The dummy accelerometers are not used in determining the occupant impact velocity, only the vehicle accelerometers.)

Due to technical difficulties there was no accelerometers data for Test 389 (Truck), Test 391 (All) and Test 392 (Occupant Impact Velocity), data previously used in this report for these test was film data.

Figure C1 , CAR AND TRUCK ACCELERATION VS TIME
TEST 371

Truck Mounted Attenuator

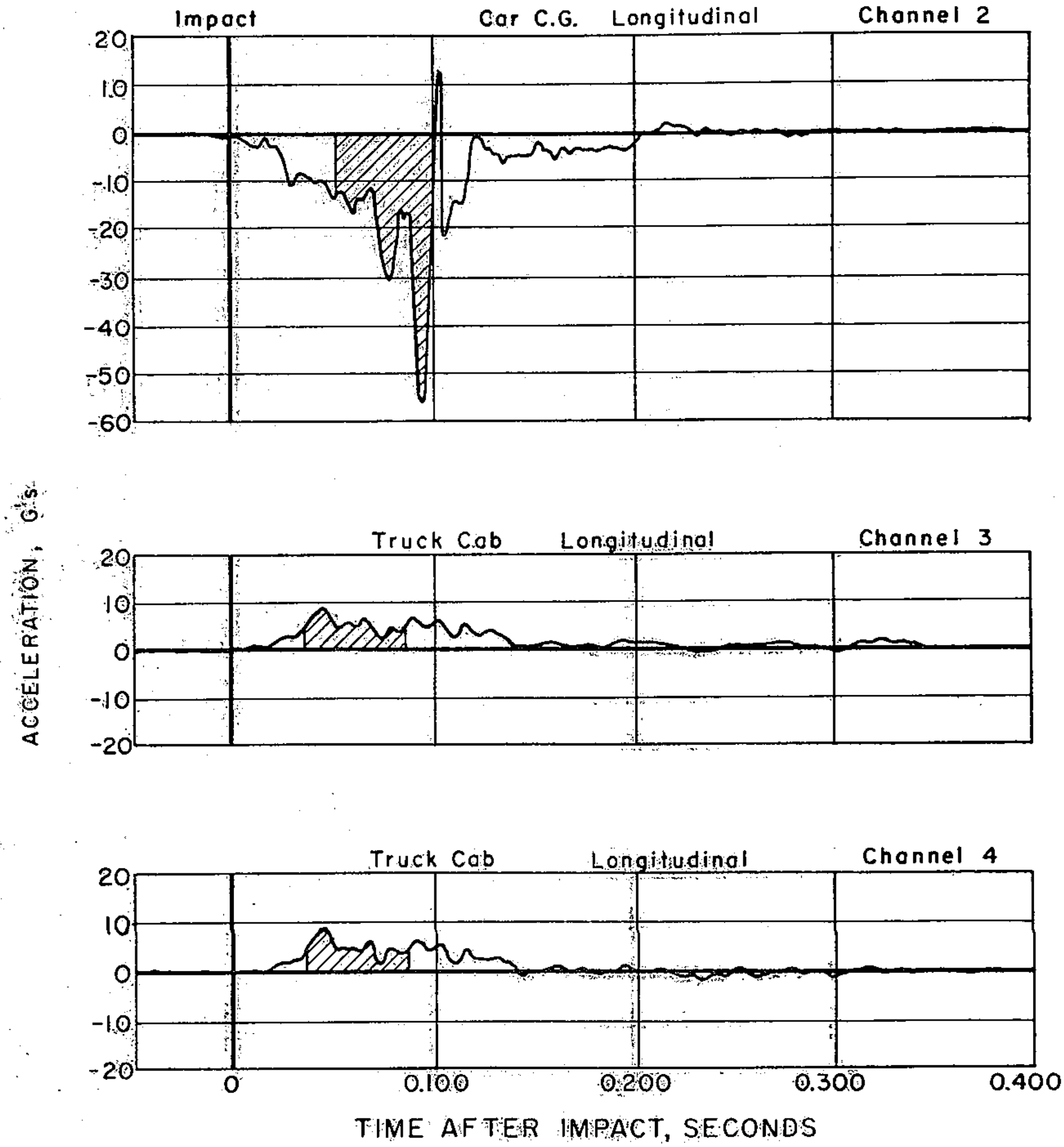


Figure C2, DUMMY ACCELERATION VS TIME
TEST 371
Truck Mounted Attenuator

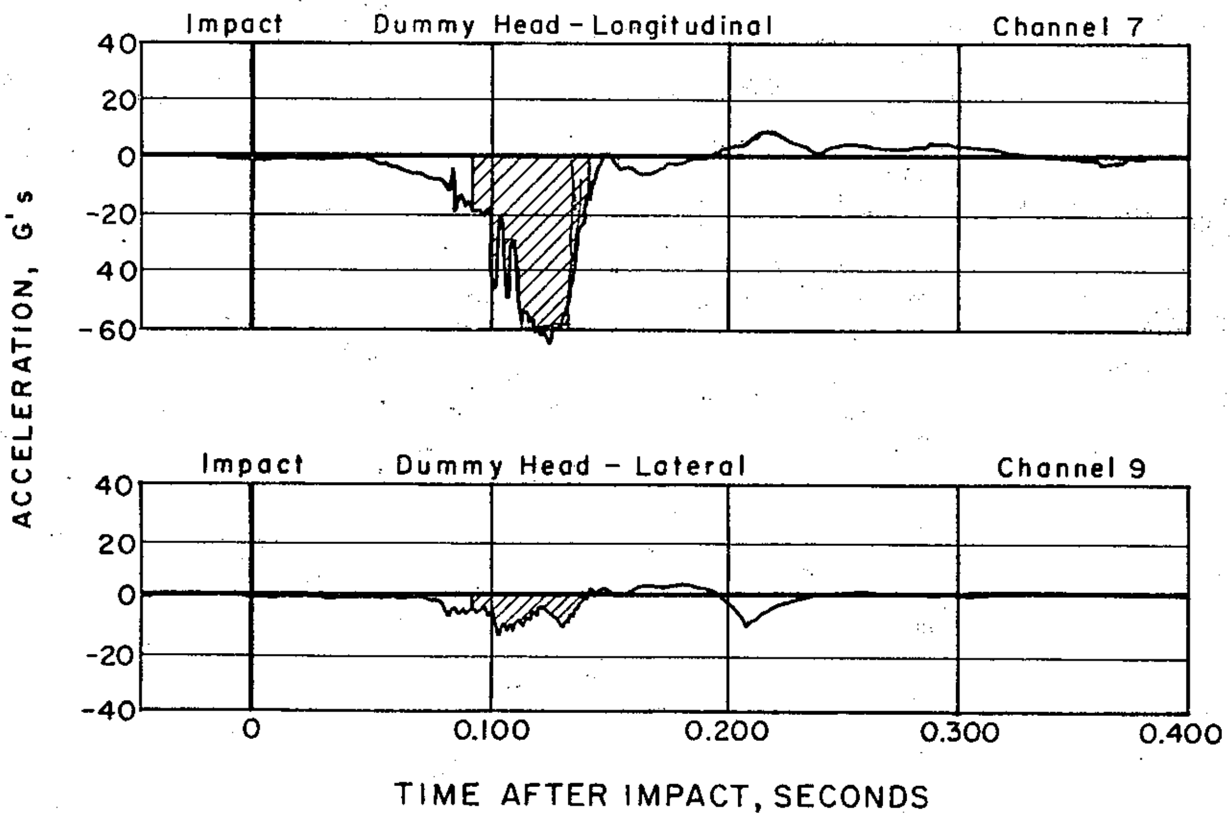


FIGURE C3 - TEST 381

TEST NUMBER
381.00
TRUCK
MOUNTED
ATTENUATOR
OCT 23 1980

MAX. 50 MS
AVER. ACCEL.
FOR CAR (G)-

VERTICAL---
-4.5953
FROM TIME(S)
.21900

LONGITUDINAL
-11.402
FROM TIME(S)
.14900

LATERAL---
3.0860
FROM TIME(S)
1.0000E-03

LATERAL---
-1.4432
FROM TIME(S)
9.6000E-02

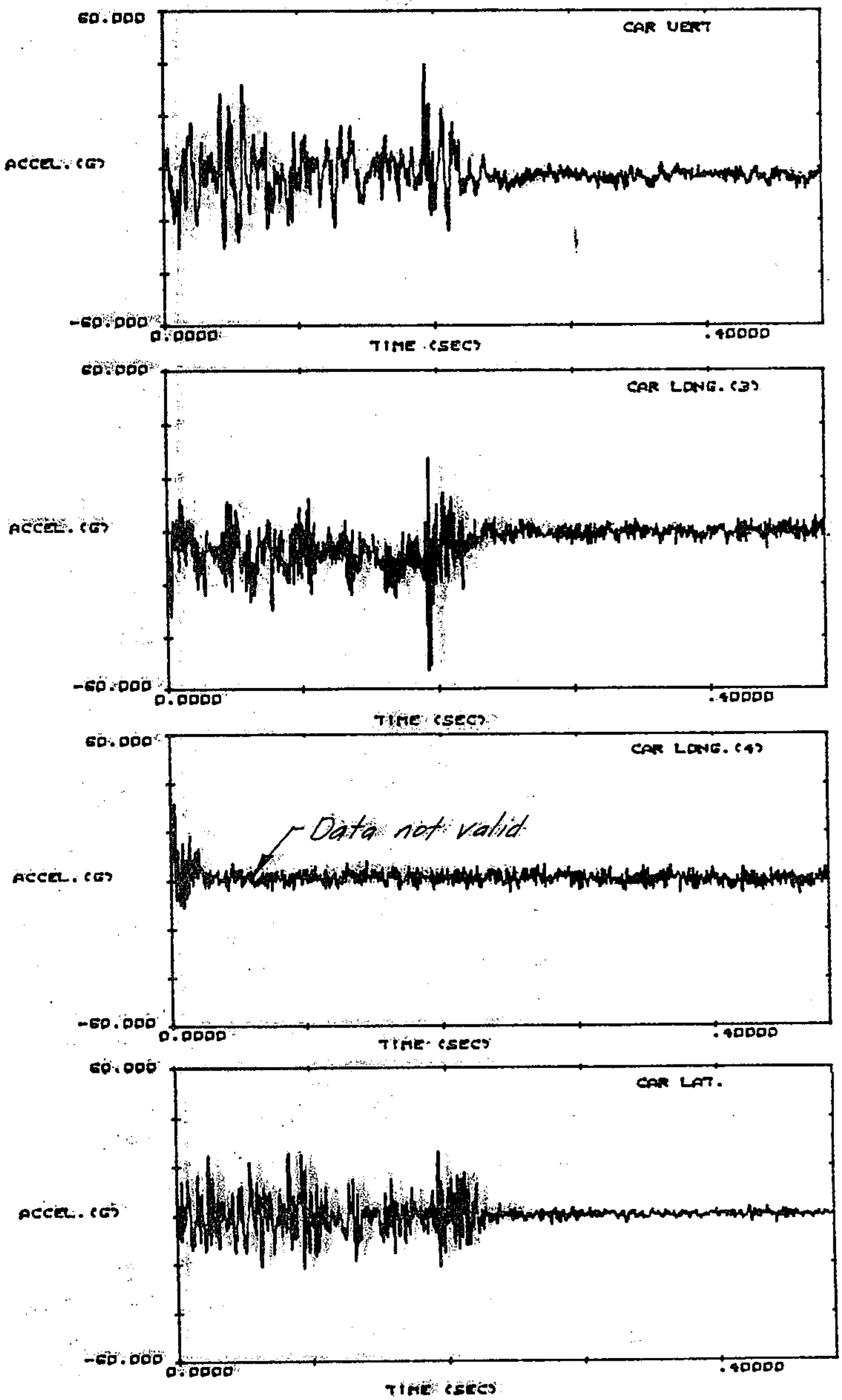


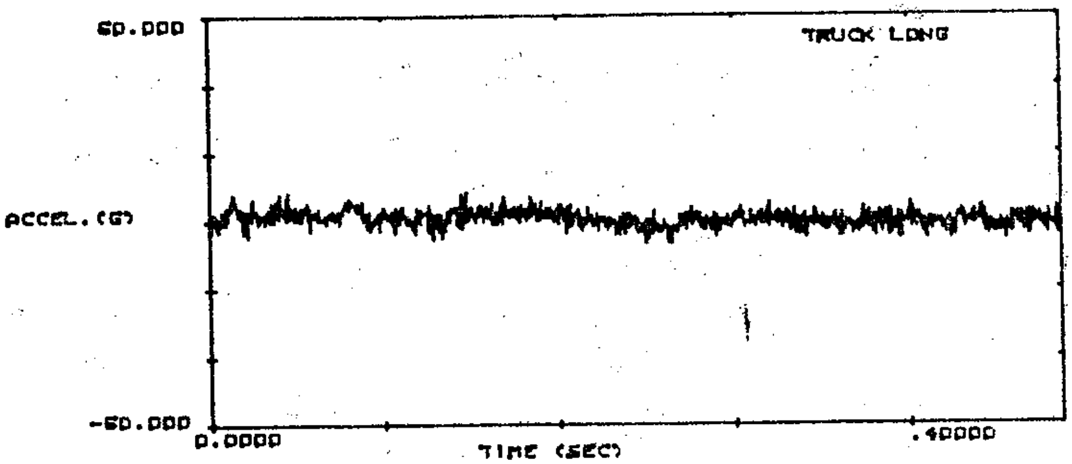
FIGURE C4 - TEST 381

TEST NUMBER
381.00
TRUCK
MOUNTED
ATTENUATOR
OCT 23 1980

MAX. 50 MS
AVER. ACCEL.
FOR TRUCK(G)

LONGITUDINAL
2.4086
FROM TIME(S)
3.8500E-02

LONGITUDINAL
4.7260
FROM TIME(S)
.13950



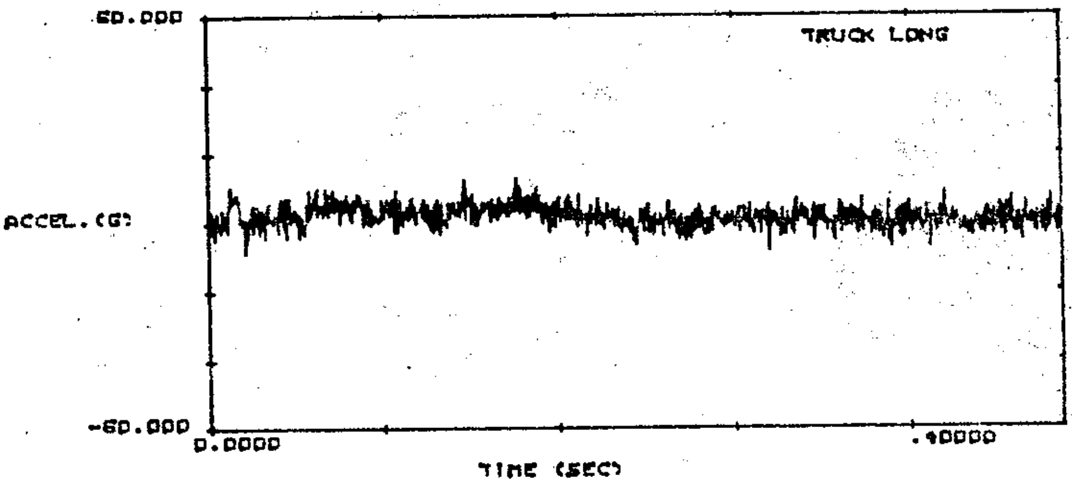


FIGURE C5 - TEST 381

TEST NUMBER
381.00
TRUCK
MOUNTED
ATTENUATOR
OCT 23 1980

CAR IMPACT
VELOCITY
(FPS)-
62.224

AT CAR
DISTANCE(FT)
6.8065
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
31.638
OCCURS AT
.13100
SEC. AFTER
CAR IMPACT

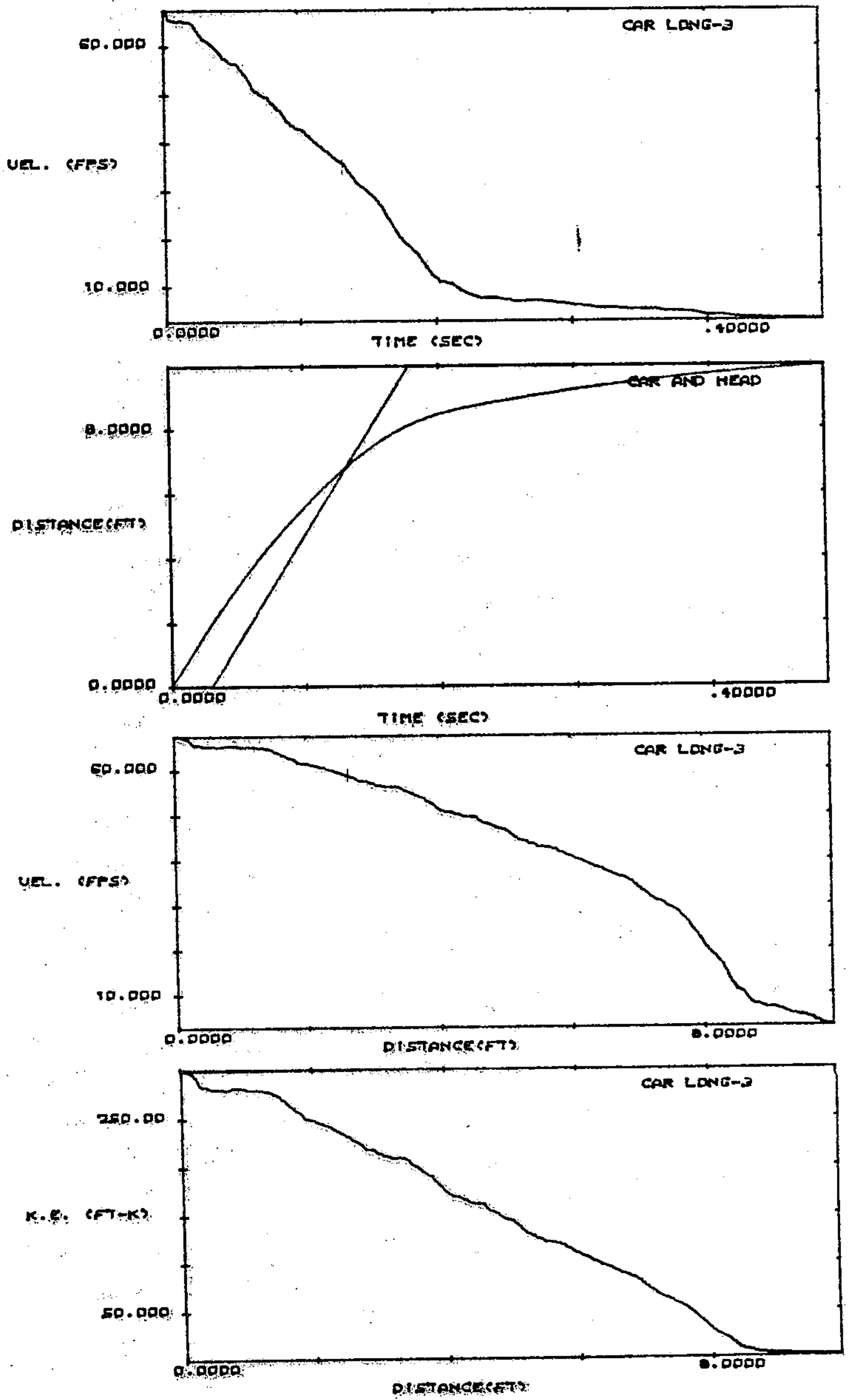


FIGURE C6 - TEST 381

TEST NUMBER
381.00
TRUCK
MOUNTED
ATTENUATOR
OCT 23 1980

TRUCK WEIGHT
(POUNDS)-
11970.
MASS(SLUGS)-
.37174

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)

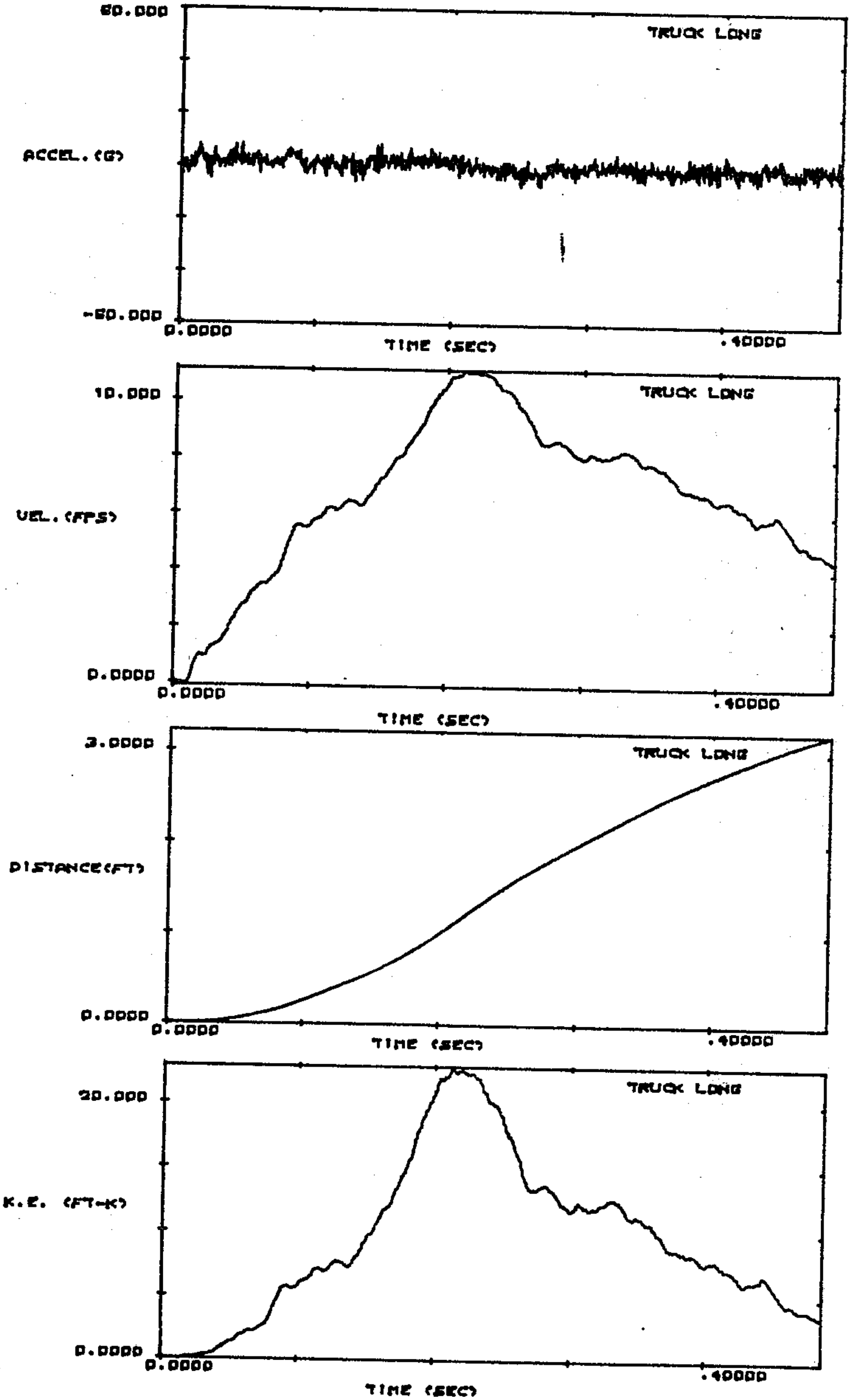


FIGURE C7 - TEST 382

TEST NUMBER

382.00

TRUCK

MOUNTED

ATTENUATOR

DEC 18 1980

MAX. 50 MS

AVER. ACCEL.

FOR CAR (G)-

VERTICAL---

4.5801

FROM TIME(S)

.14150

LONGITUDINAL

-12.369

FROM TIME(S)

.12900

LONGITUDINAL

-11.826

FROM TIME(S)

.12850

LATERAL---

-4.2582

FROM TIME(S)

.19700

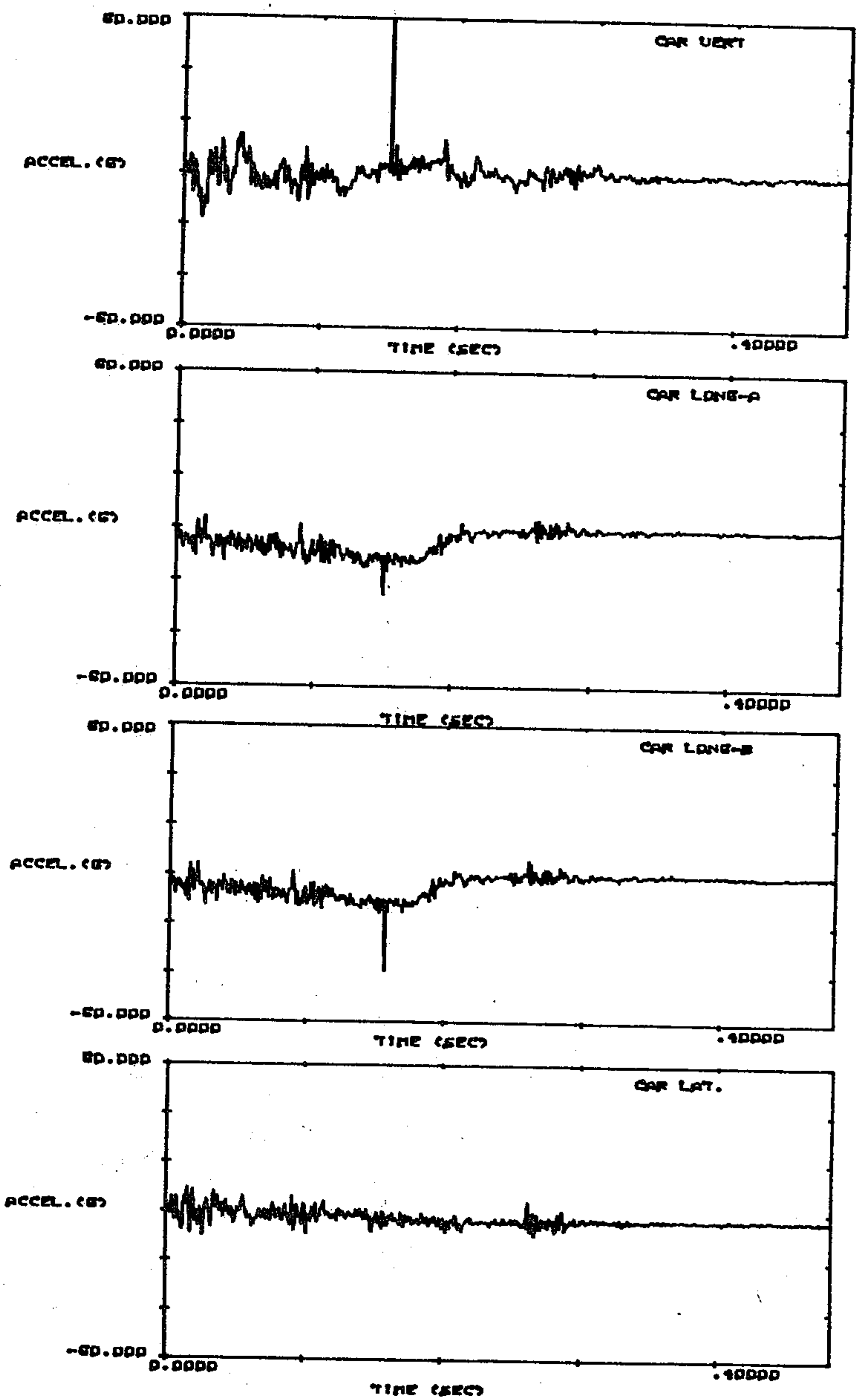


FIGURE C8 - TEST 382

TEST NUMBER
382.00
TRUCK
MOUNTED
ATTENUATOR
DEC 18 1980

CAR IMPACT
VELOCITY
(FPS)-
64.343

AT CAR
DISTANCE(FT)
7.0394
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
34.336
OCCURS AT
.14050
SEC. AFTER
CAR IMPACT

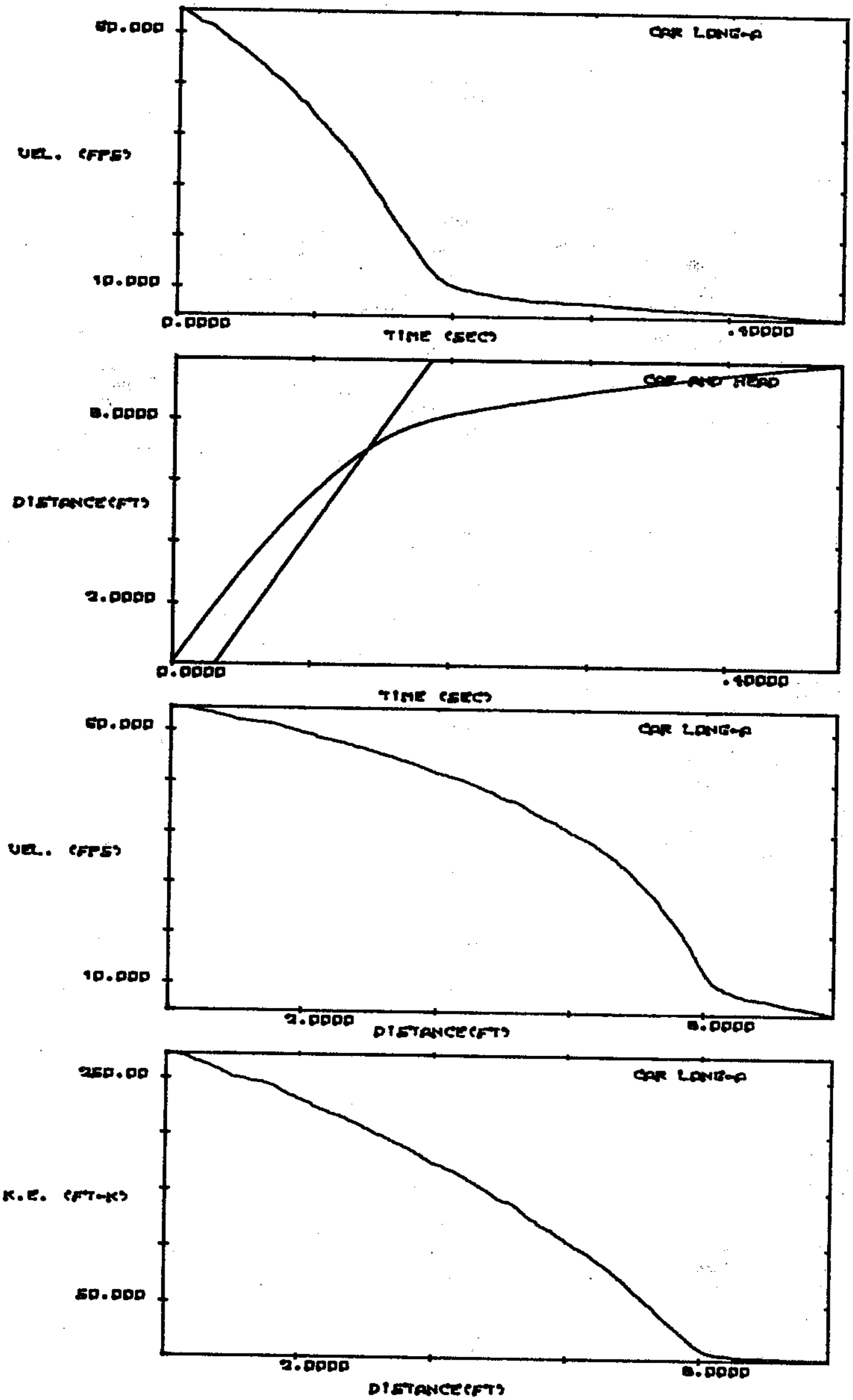


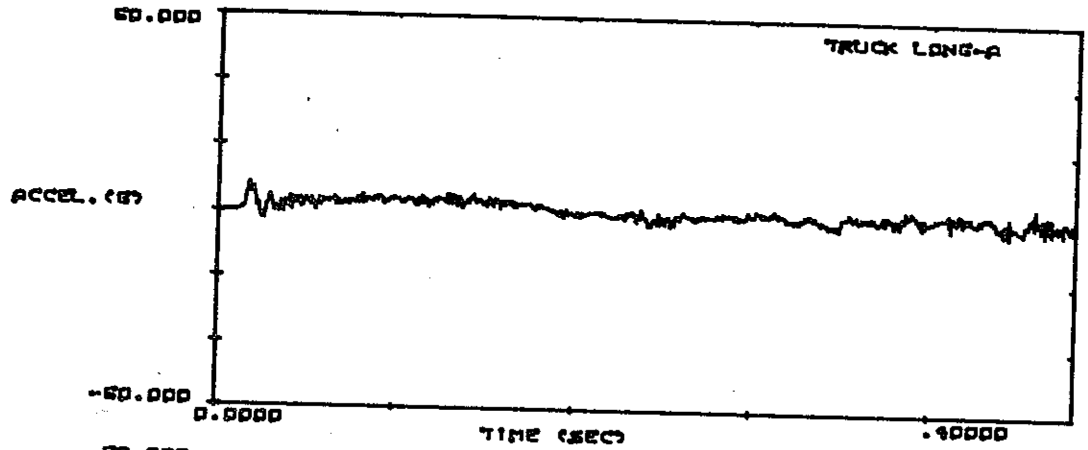
FIGURE C9 - TEST 382

TEST NUMBER
382.00
TRUCK
MOUNTED
ATTENUATOR
DEC 18 1980

MAX. 50 MS
AVER. ACCEL.
FOR TRUCK(G)

LONGITUDINAL
3.6852
FROM TIME(S)
8.7000E-02

LONGITUDINAL
-3.7968
FROM TIME(S)
.10850



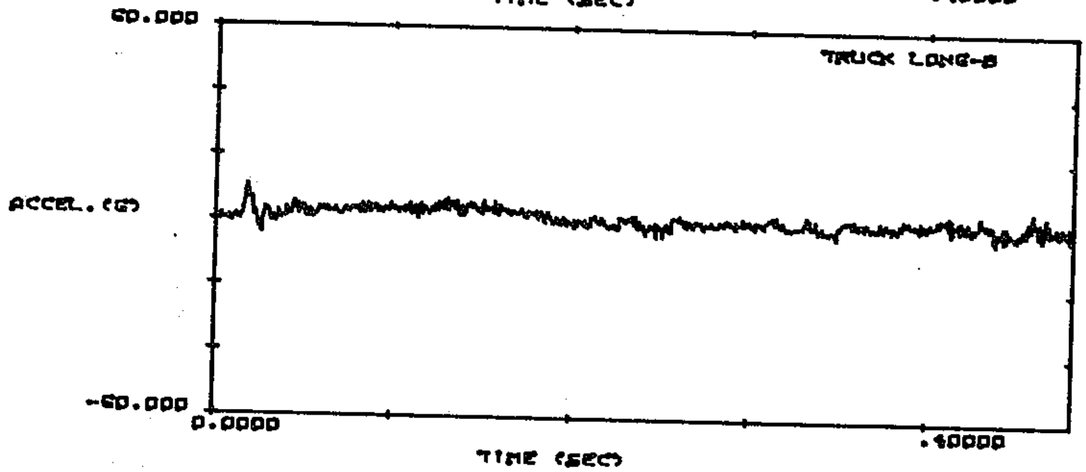


FIGURE C10 - TEST 382

TEST NUMBER
382.00
TRUCK
MOUNTED
ATTENUATOR
DEC 18 1980

TRUCK WEIGHT
(POUNDS)-
11970.
MASS(SLUGS)-
.37174

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)

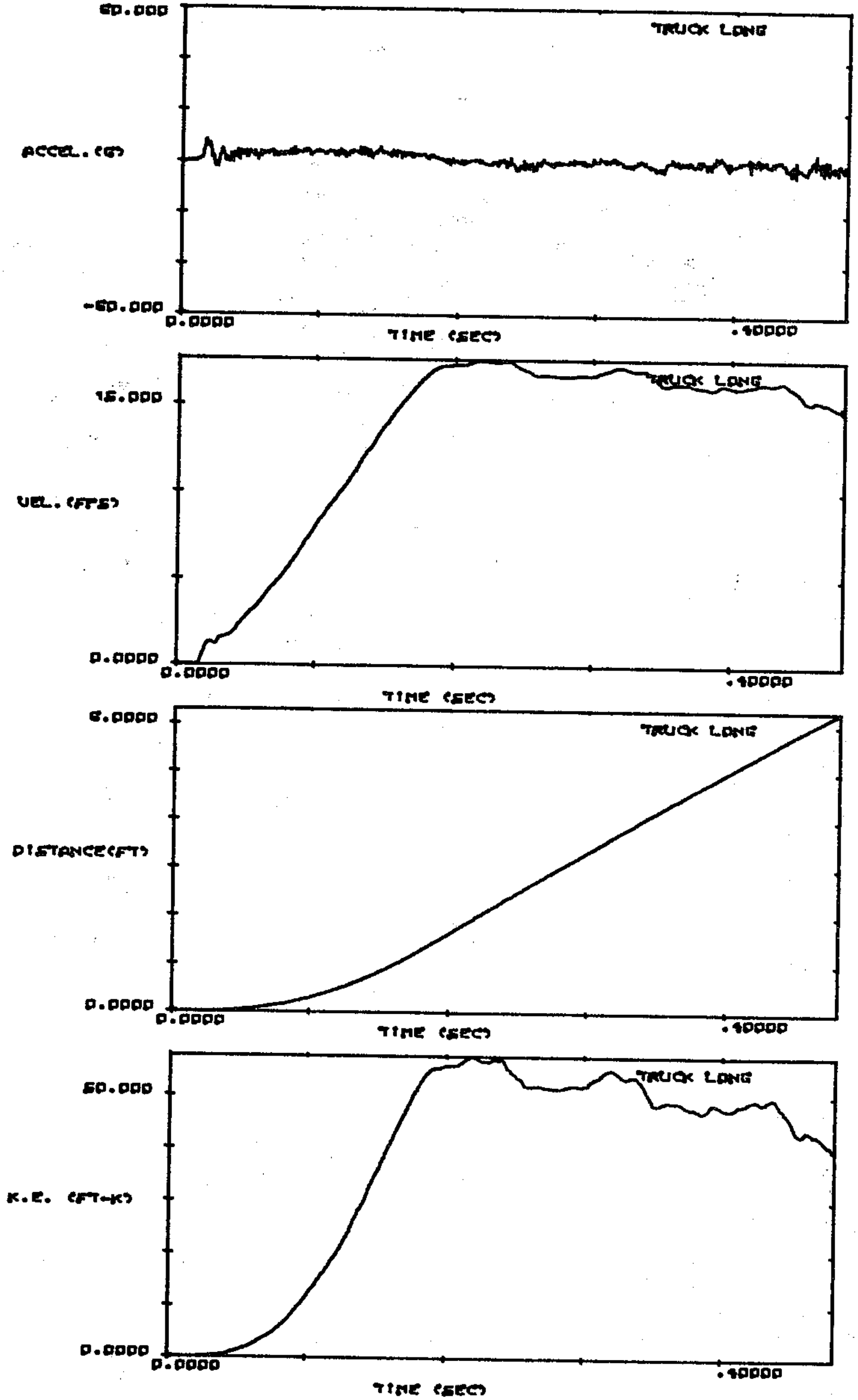


FIGURE C11 - TEST 383

TEST NUMBER
383.00
TRUCK
MOUNTED
ATTENUATOR
FEB 10 1981

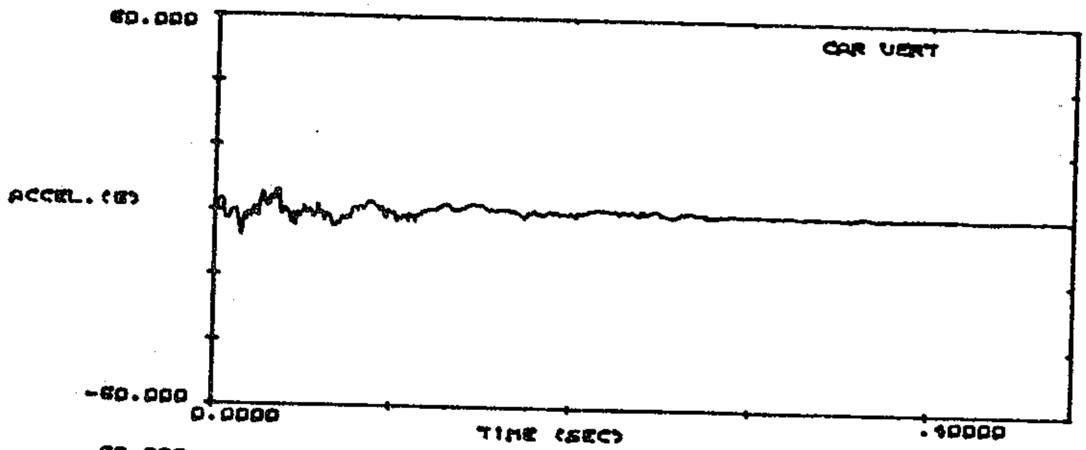
MAX. 50 MS
AVER. ACCEL.
FOR CAR (G)-

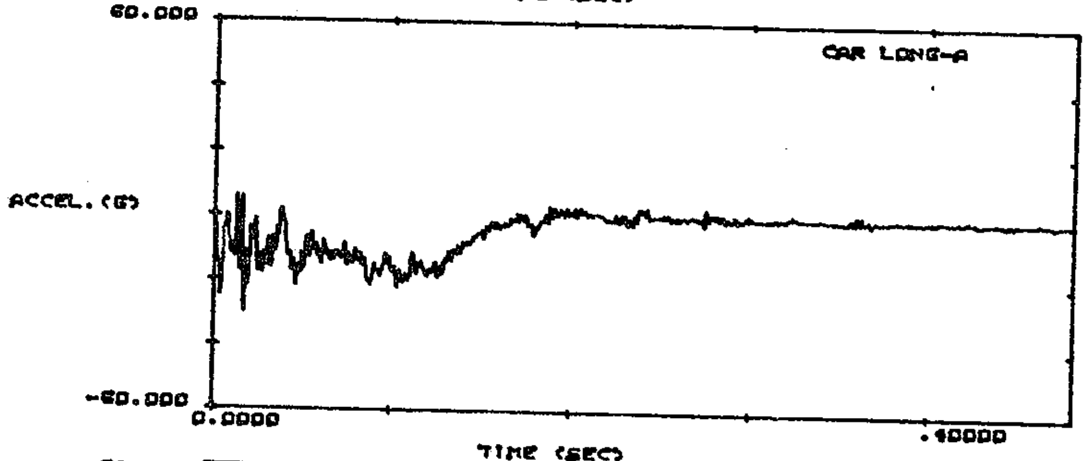
VERTICAL---
1.1272
FROM TIME(S)
.11850

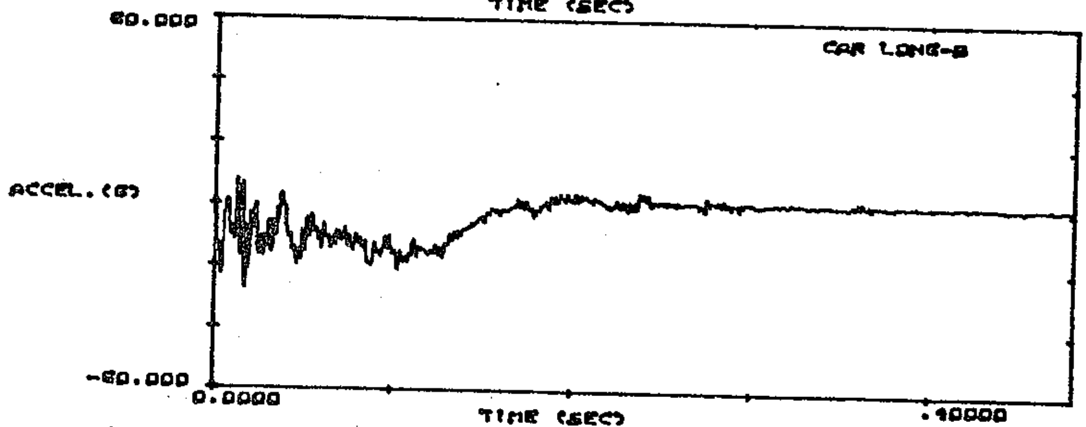
LONGITUDINAL
-16.312
FROM TIME(S)
8.0500E-02

LONGITUDINAL
-15.078
FROM TIME(S)
8.0500E-02

LATERAL---
2.5152
FROM TIME(S)
6.2500E-02







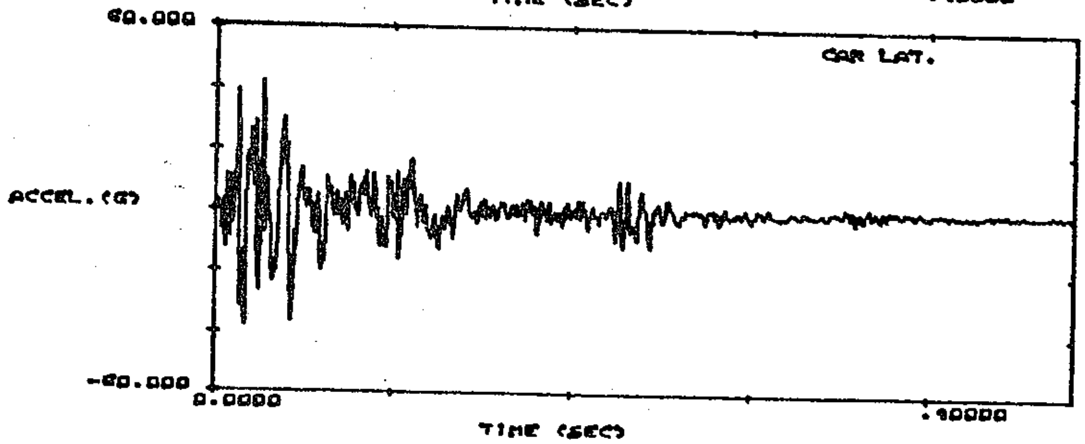


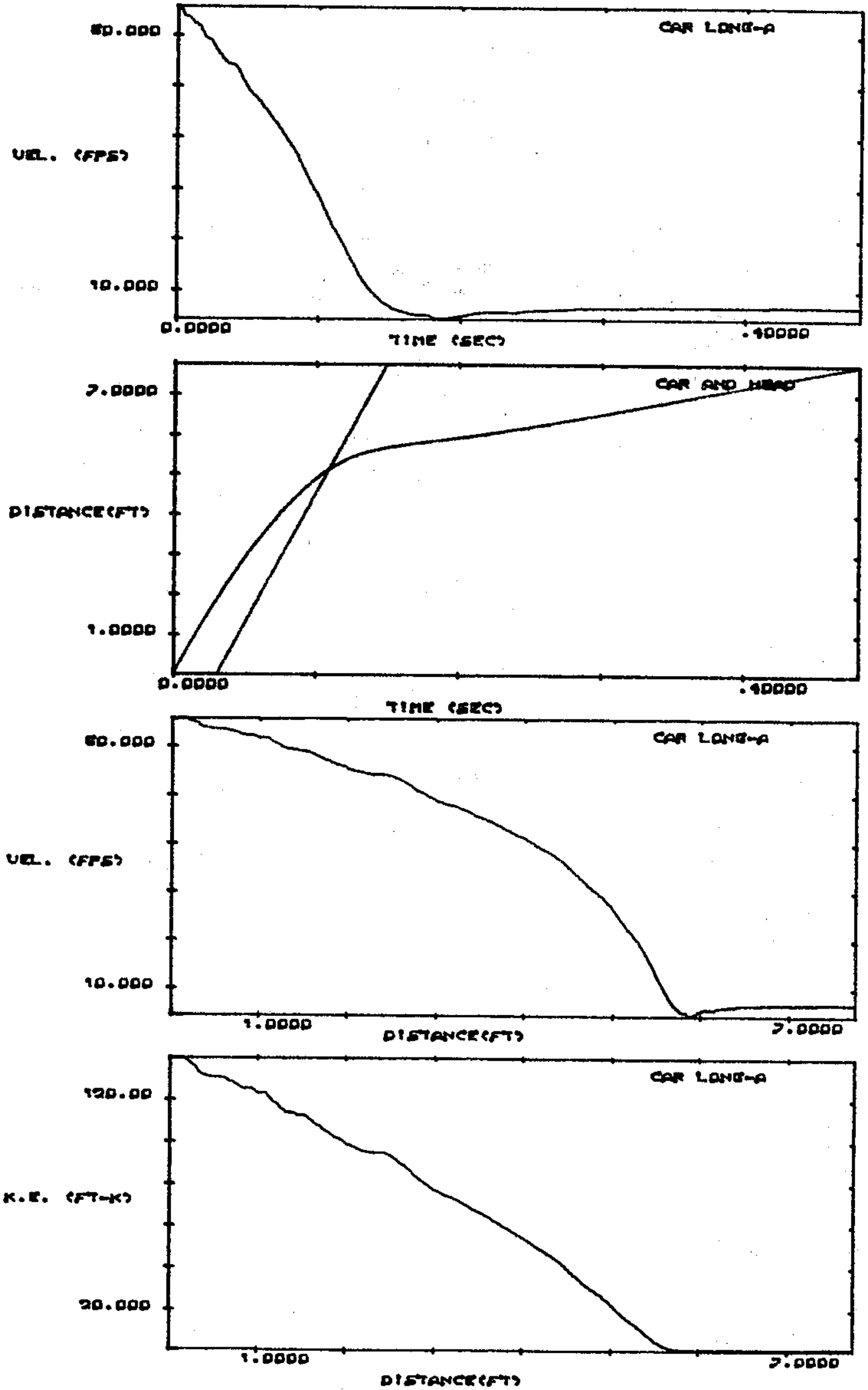
FIGURE C12 - TEST 383

TEST NUMBER
383.00
TRUCK
MOUNTED
ATTENUATOR
FEB 18 1981

CAR IMPACT
VELOCITY
(FPS)-
65.574

AT CAR
DISTANCE(FT)
5.1485
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
42.690
OCCURS AT
.10900
SEC. AFTER
CAR IMPACT



TEST NUMBER
383.00
TRUCK
MOUNTED
ATTENUATOR
FEB 18 1981

MAX. 50 MS
AVER. ACCEL.
FOR TRUCK(G)

LONGITUDINAL
3.1155
FROM TIME(S)
5.5500E-02

LONGITUDINAL
3.4586
FROM TIME(S)
5.6000E-02

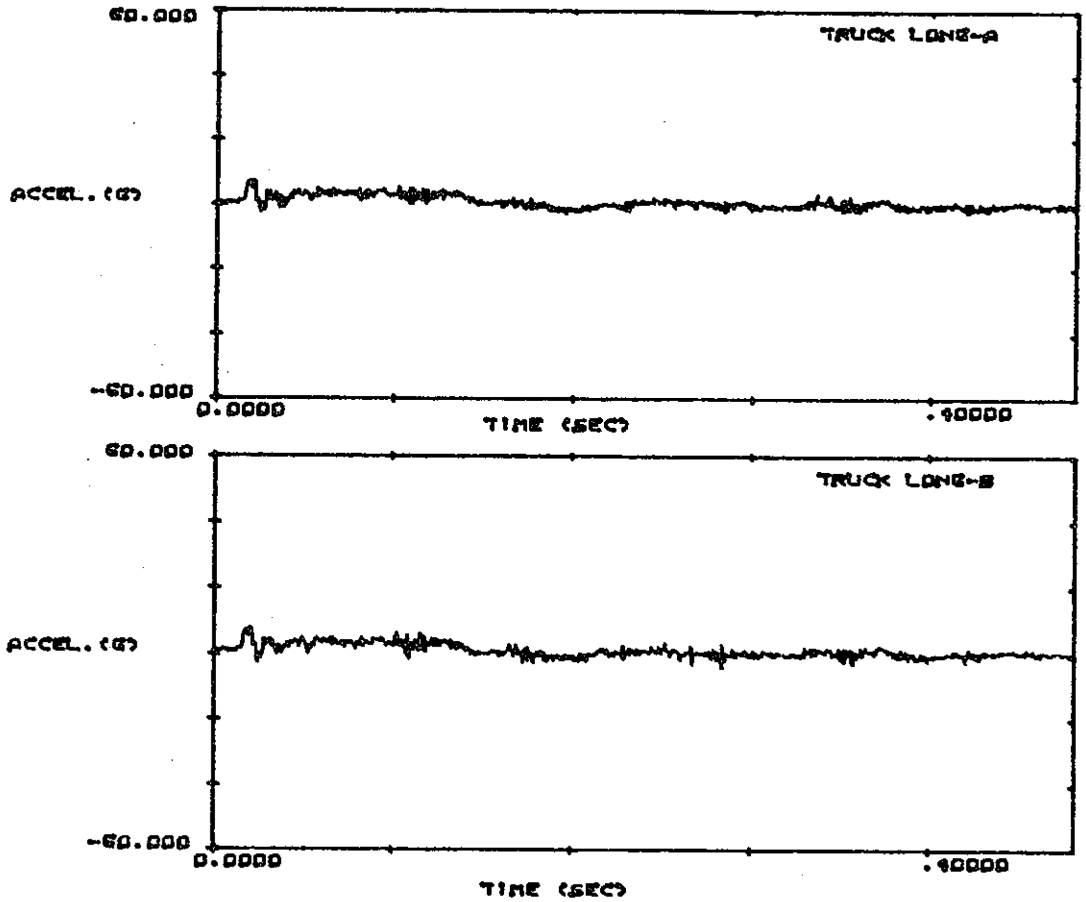


FIGURE C14 - TEST 383

TEST NUMBER
383.00
TRUCK
MOUNTED
ATTENUATOR
FEB 18 1981

TRUCK WEIGHT
(POUNDS)-
11970.
MASS(SLUGS)-
.37174

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)

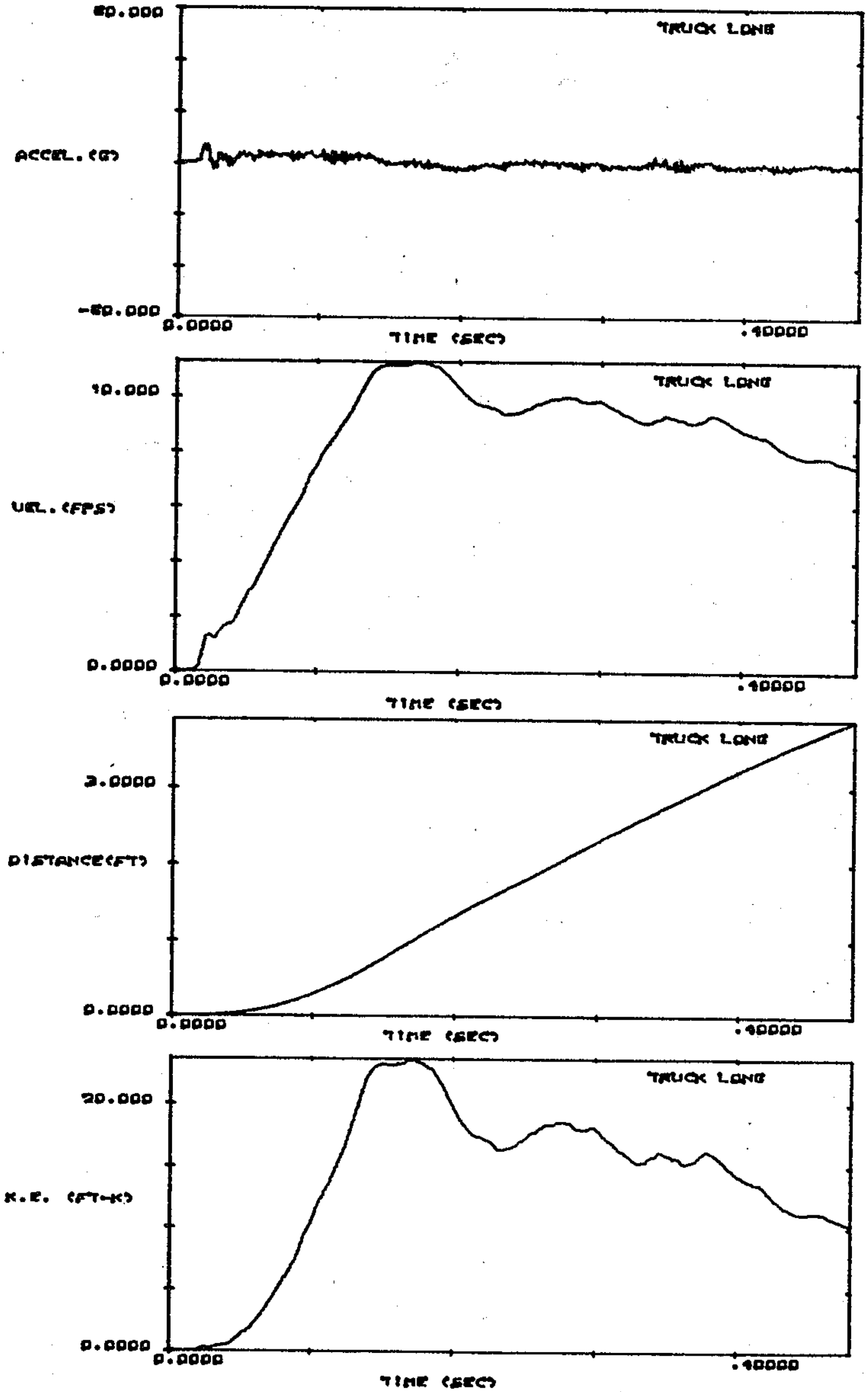


FIGURE C15 - TEST 384

TEST NUMBER

384.00

TRUCK

MOUNTED

ATTENUATOR

APRIL 9 1981

MAX. 50 MS

AVER. ACCEL.

FOR CAR (G)-

VERTICAL---

4.5114

FROM TIME(S)

.15750

LONGITUDINAL

-16.175

FROM TIME(S)

.11350

LONGITUDINAL

-15.795

FROM TIME(S)

.11400

LATERAL---

.93568

FROM TIME(S)

.13750

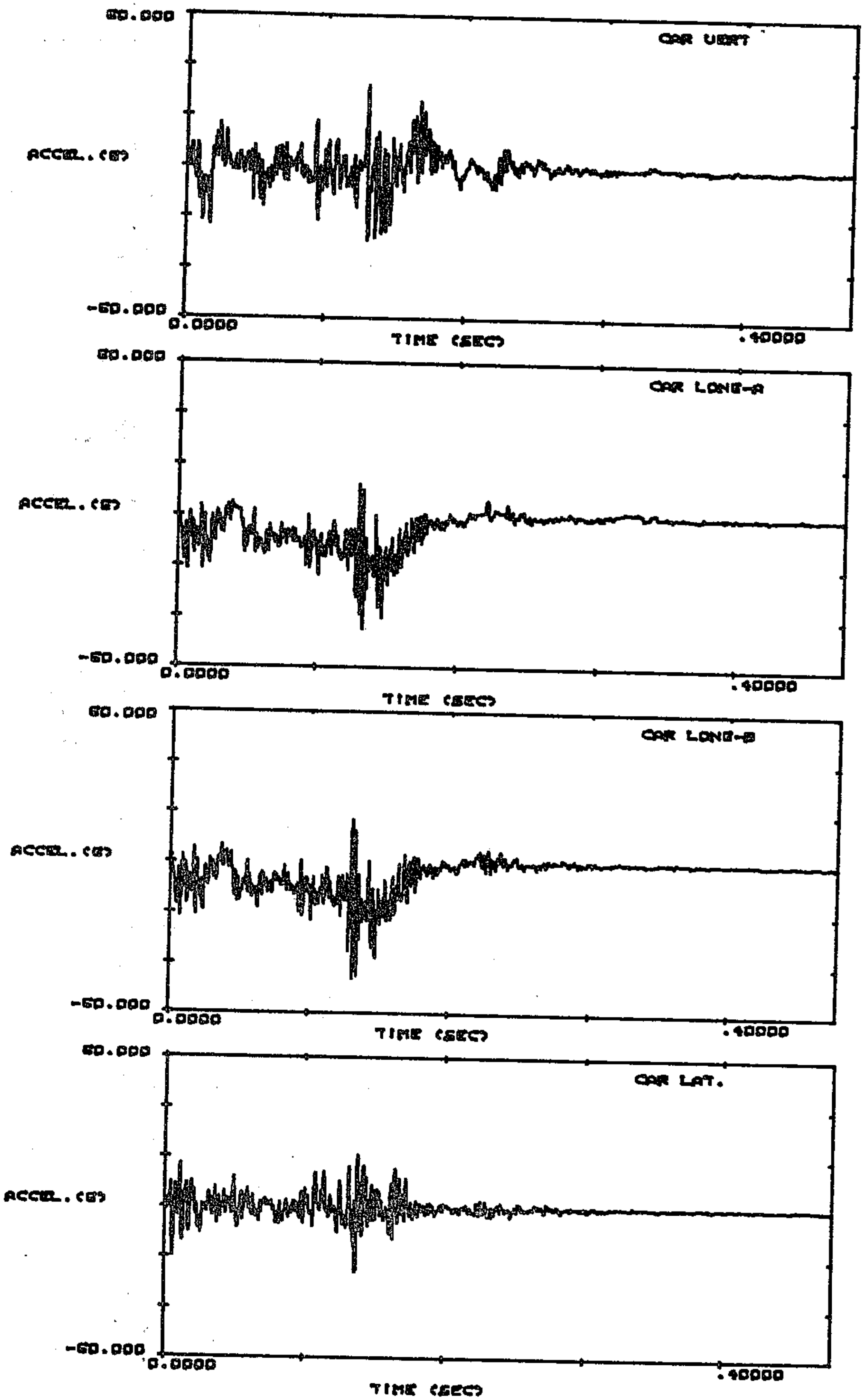


FIGURE C16 - TEST 384

TEST NUMBER
384.00
TRUCK
MOUNTED
ATTENUATOR
APRIL 9 1981

CAR IMPACT
VELOCITY
(FPS)-
63.325

AT CAR
DISTANCE(FT)
6.3907
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
36.757
OCCURS AT
.13250
SEC. AFTER
CAR IMPACT

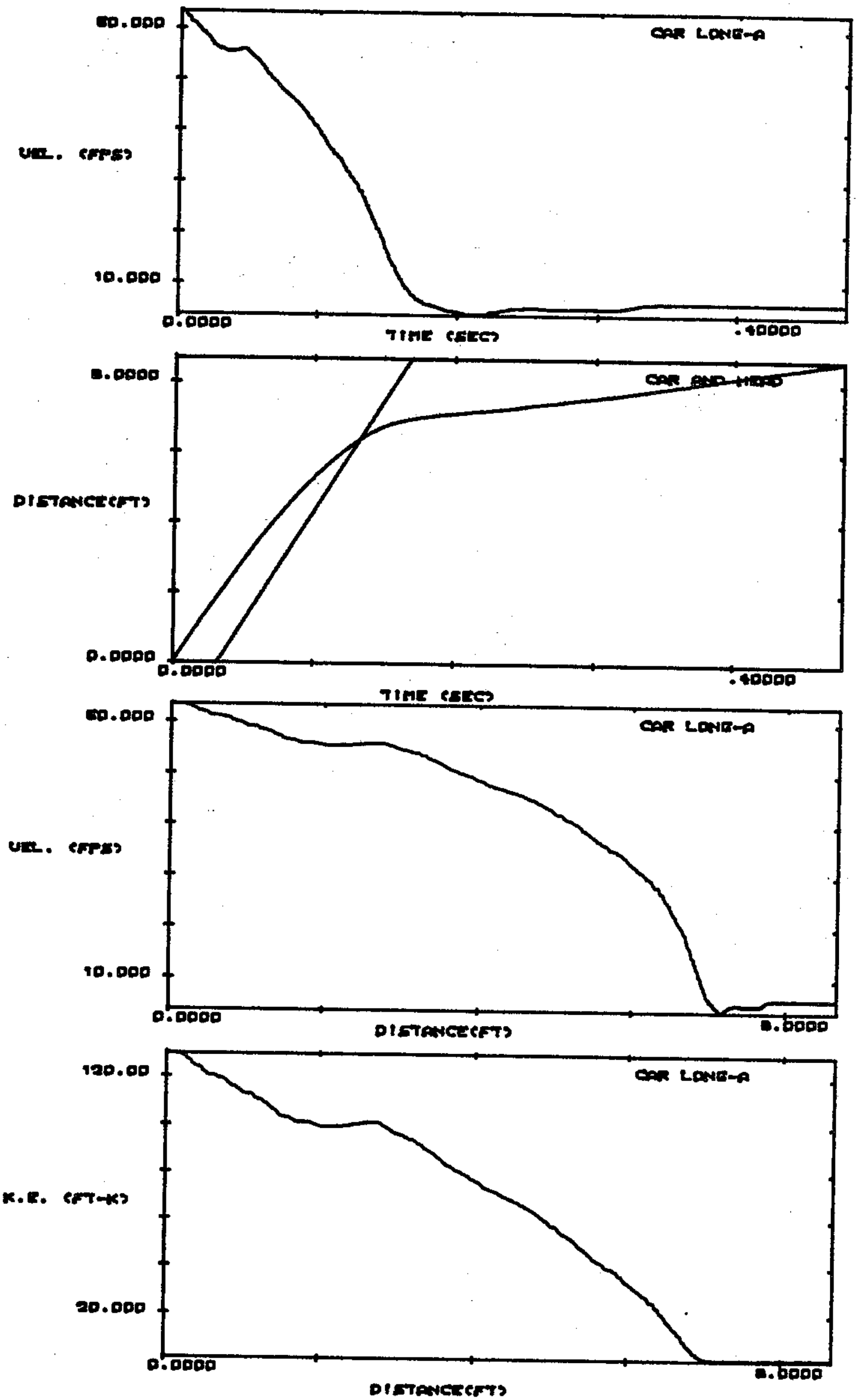


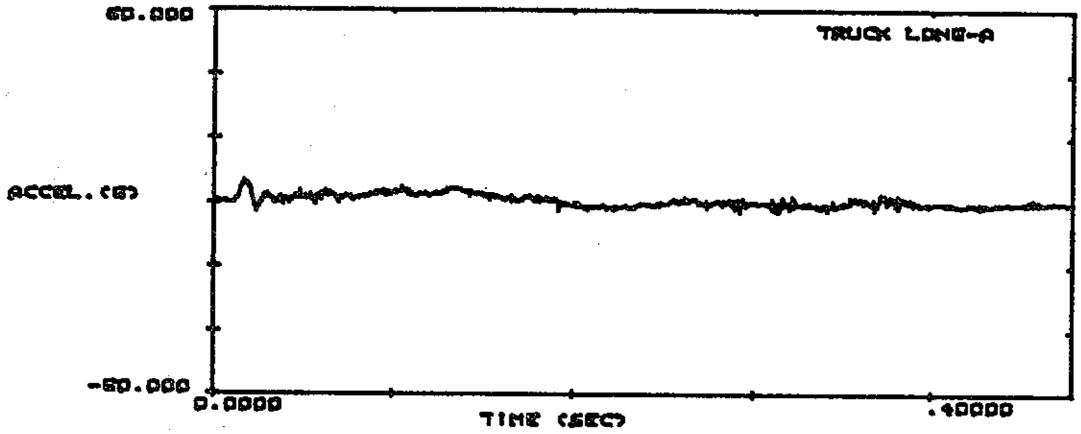
FIGURE C17 - TEST 384

TEST NUMBER
384.00
TRUCK
MOUNTED
ATTENUATOR
APRIL 9 1981

MAX. 50 MS
AVER. ACCEL.
FOR TRUCK(G)

LONGITUDINAL
2.9453
FROM TIME(S)
9.2500E-02

LONGITUDINAL
2.5297
FROM TIME(S)
9.1500E-02



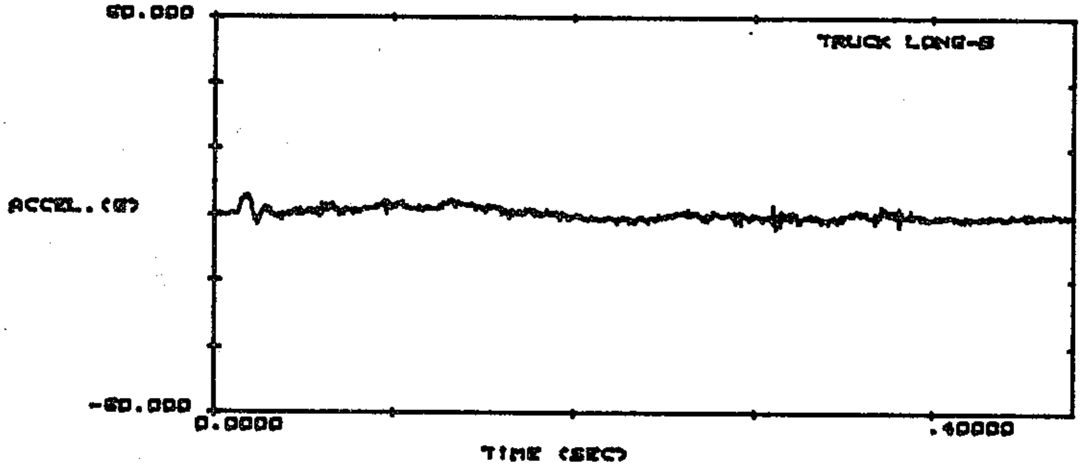


FIGURE C18 - TEST 384

TEST NUMBER
384.00
TRUCK
MOUNTED
ATTENUATOR
APRIL 9 1981

TRUCK WEIGHT
(POUNDS)-
11970.
MASS(SLUGS)-
.37174

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)

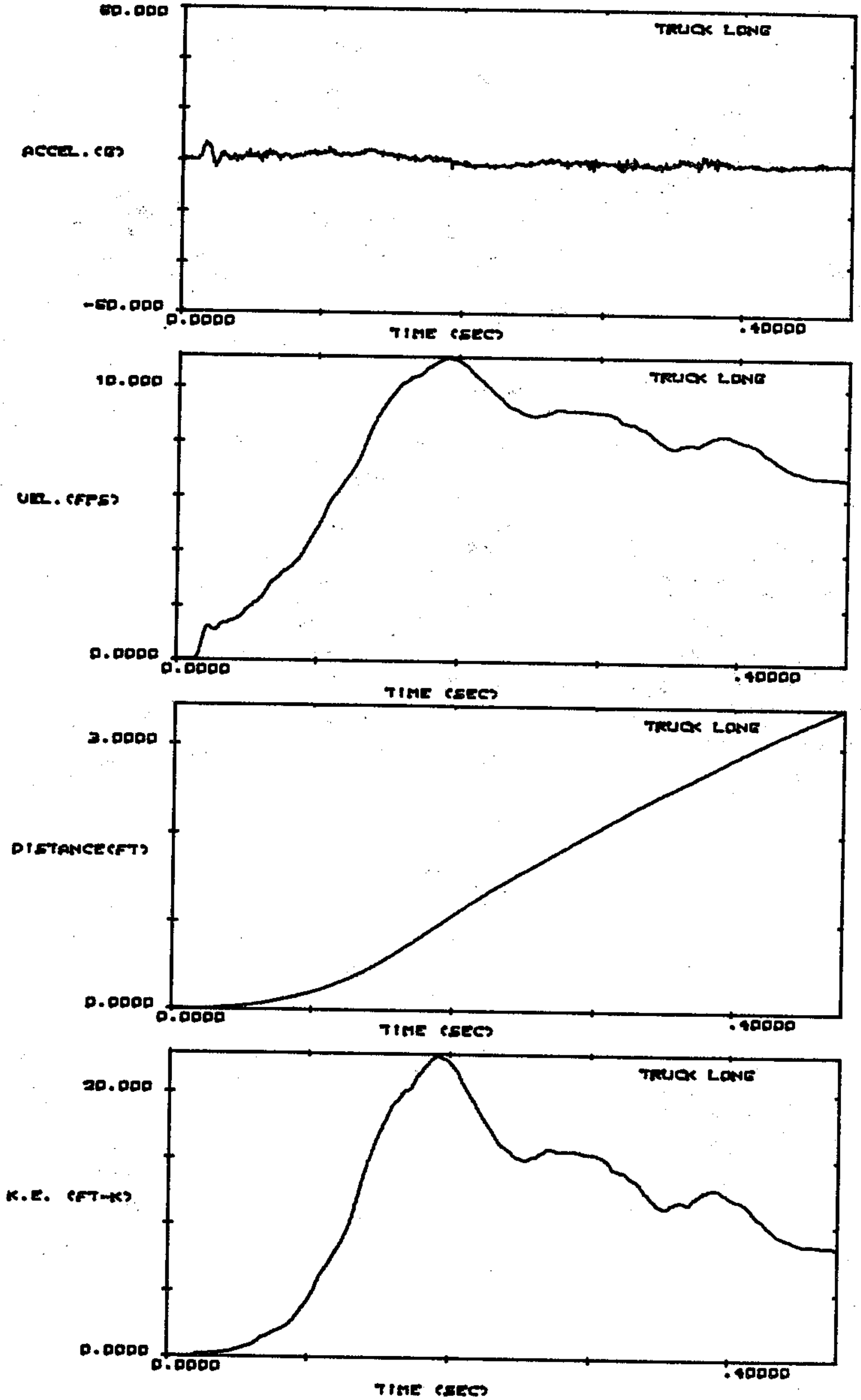


FIGURE C19 - TEST 385

TEST NUMBER

385.00

TRUCK

MOUNTED

ATTENUATOR

MAY 7 1981

MAX. 50 MS

AVER. ACCEL.

FOR CAR (G)-

VERTICAL---

4.9574

FROM TIME(S)

.14950

LONGITUDINAL

-15.387

FROM TIME(S)

.11800

LONGITUDINAL

-14.931

FROM TIME(S)

.11750

LATERAL---

-1.9097

FROM TIME(S)

4.5500E-02

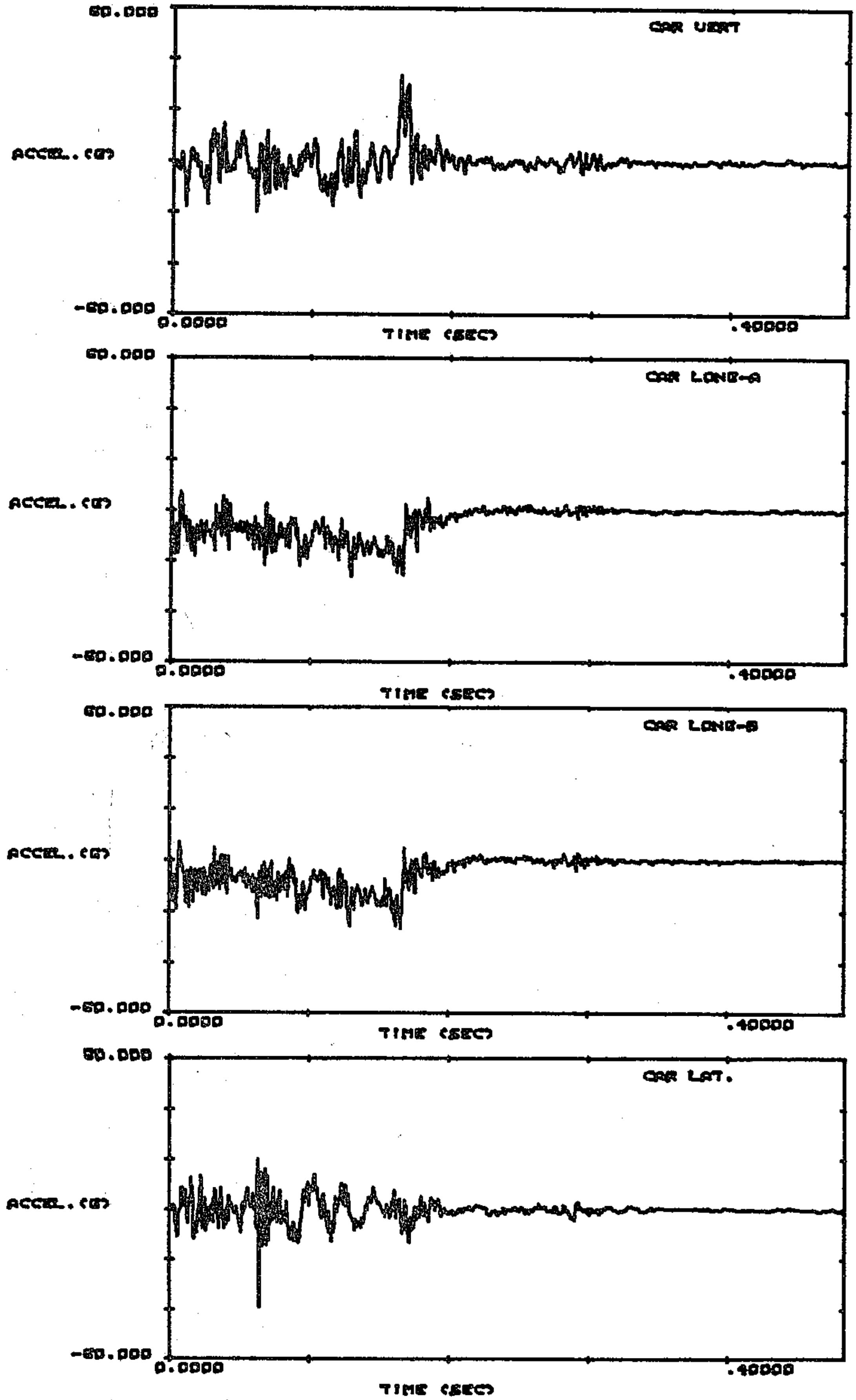


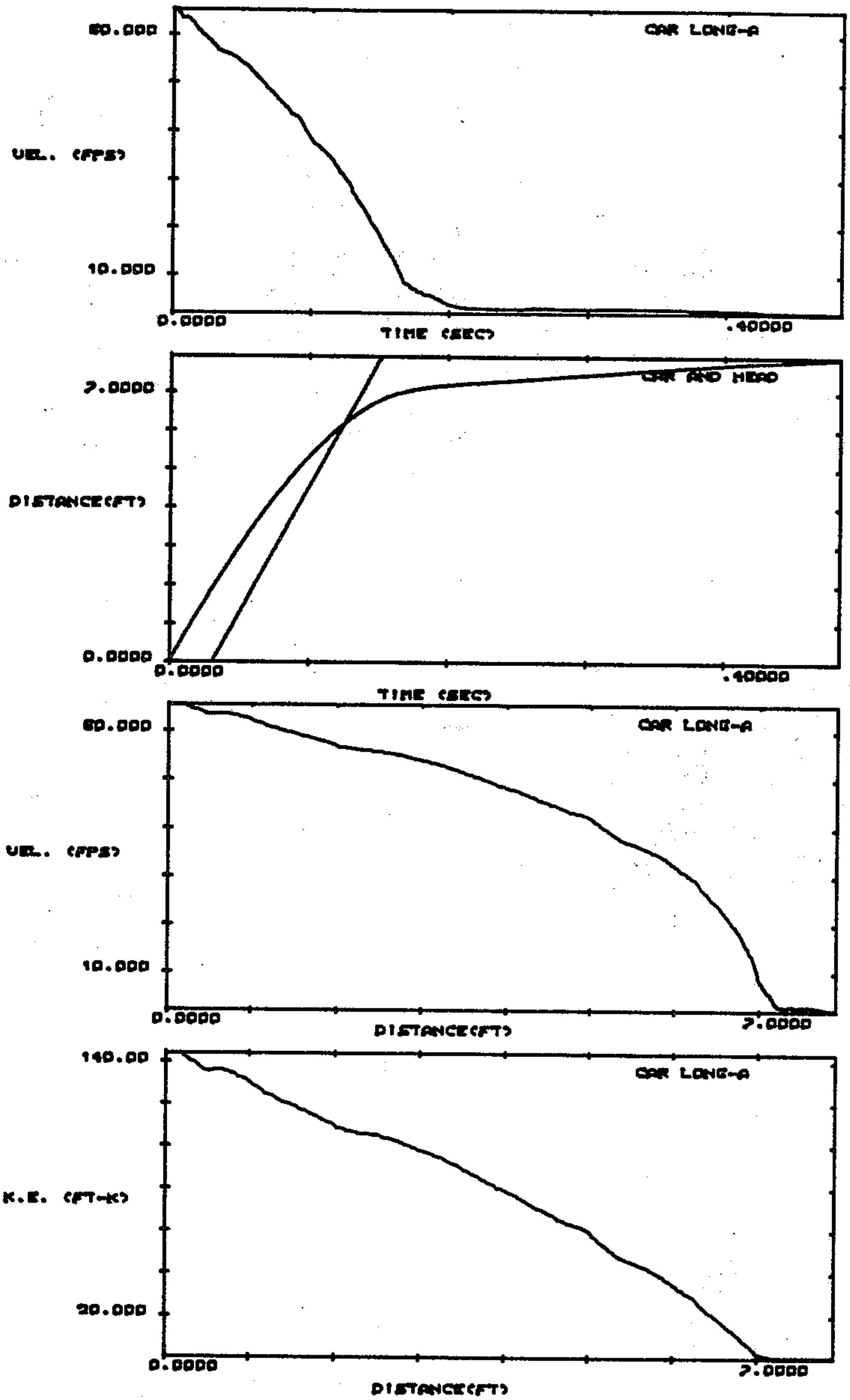
FIGURE C20 - TEST 385

TEST NUMBER
385.00
TRUCK
MOUNTED
ATTENUATOR
MAY 7 1981

CAR IMPACT
VELOCITY
(FPS)-
65.146

AT CAR
DISTANCE(FT)
6.2089
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
35.605
OCCURS AT
.12600
SEC. AFTER
CAR IMPACT

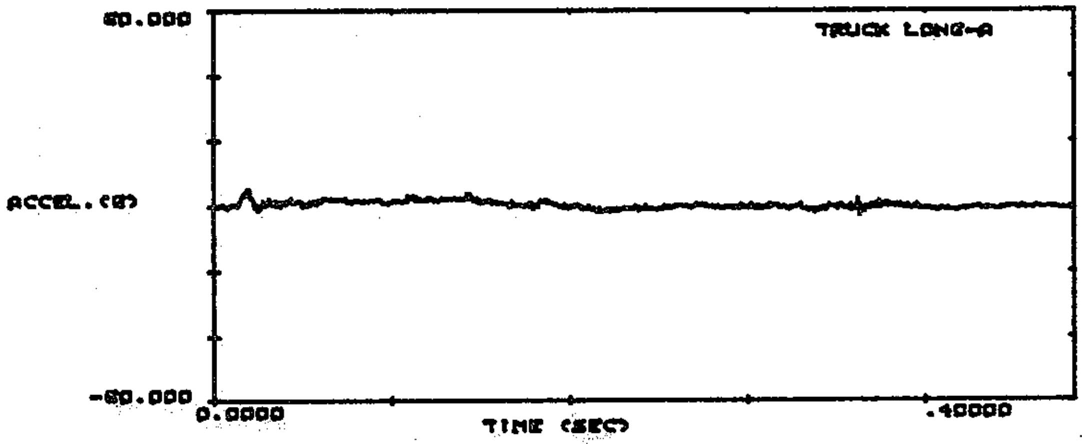


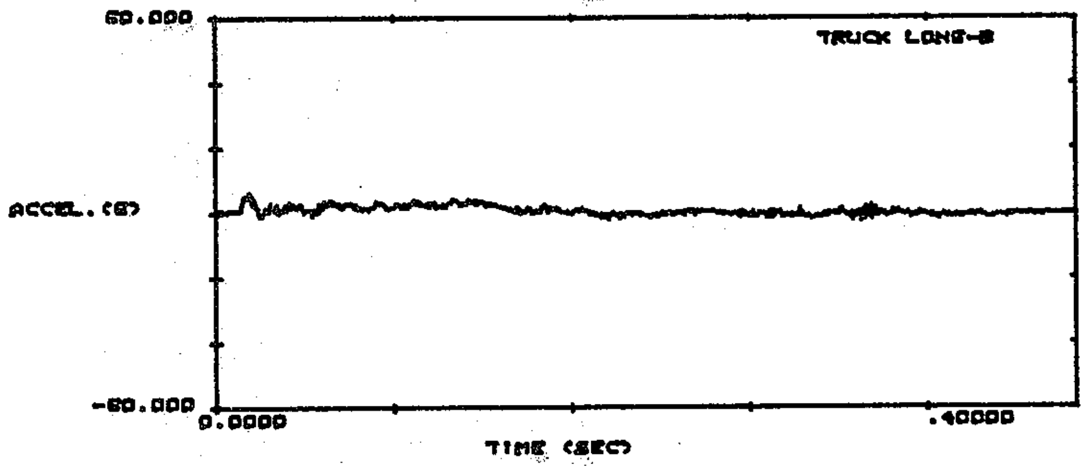
TEST NUMBER
385.00
TRUCK
MOUNTED
ATTENUATOR
MAY 7 1981

MAX. 50 MS
AVER. ACCEL.
FOR TRUCK(G)

LONGITUDINAL
2.0564
FROM TIME(S)
.10050

LONGITUDINAL
2.6586
FROM TIME(S)
.10900





TEST NUMBER
385.00
TRUCK
MOUNTED
ATTENUATOR
MAY 7 1981

TRUCK WEIGHT
(POUNDS)-
11970.
MASS(SLUGS)-
.37174

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)

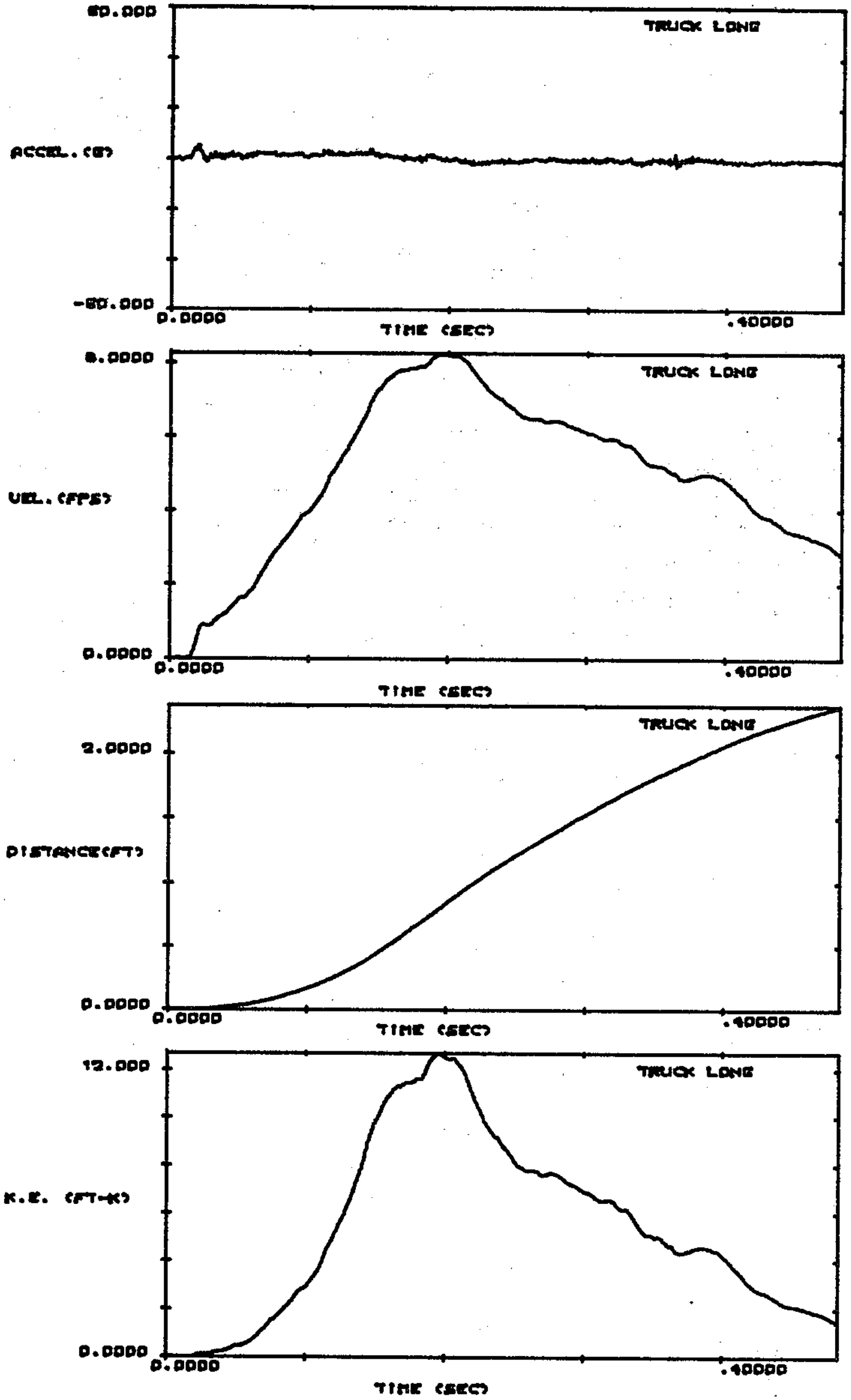


FIGURE C23 - TEST 386

TEST NUMBER
386.00
TRUCK
MOUNTED
ATTENUATOR
JUNE 11 1981

MAX. 50 MS
AVER. ACCEL.
FOR CAR (G)-

VERTICAL---
6.0916
FROM TIME(S)
.17350

LONGITUDINAL
-13.579
FROM TIME(S)
.14300

LATERAL---
1.7094
FROM TIME(S)
.21400

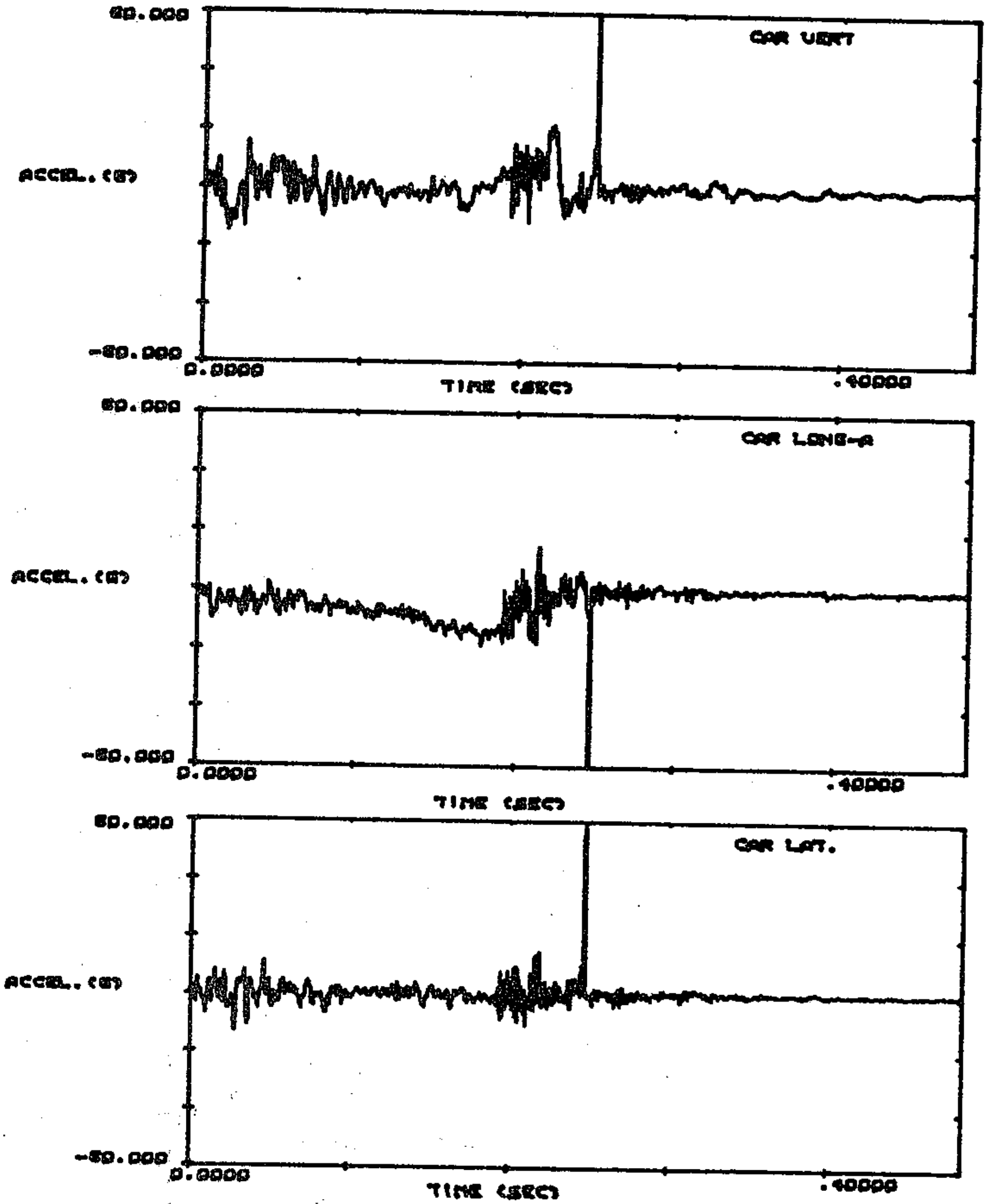


FIGURE C24 - TEST 386

TEST NUMBER
386.00
TRUCK
MOUNTED
ATTENUATOR
JUNE 11 1981

CAR IMPACT
VELOCITY
(FPS)-
65.754

AT CAR
DISTANCE(FT)
8.3222
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
32.376
OCCURS AT
.15700
SEC. AFTER
CAR IMPACT

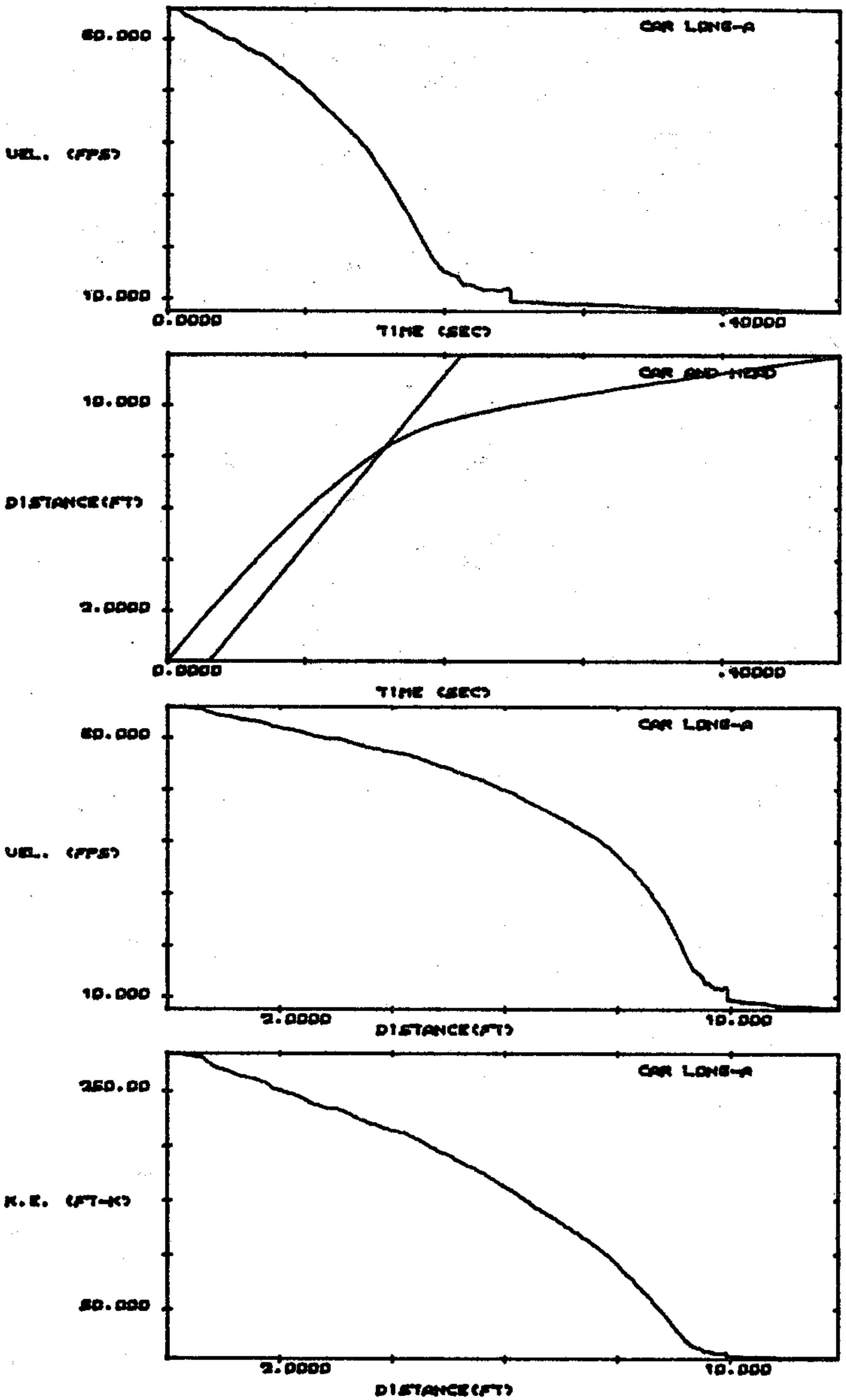


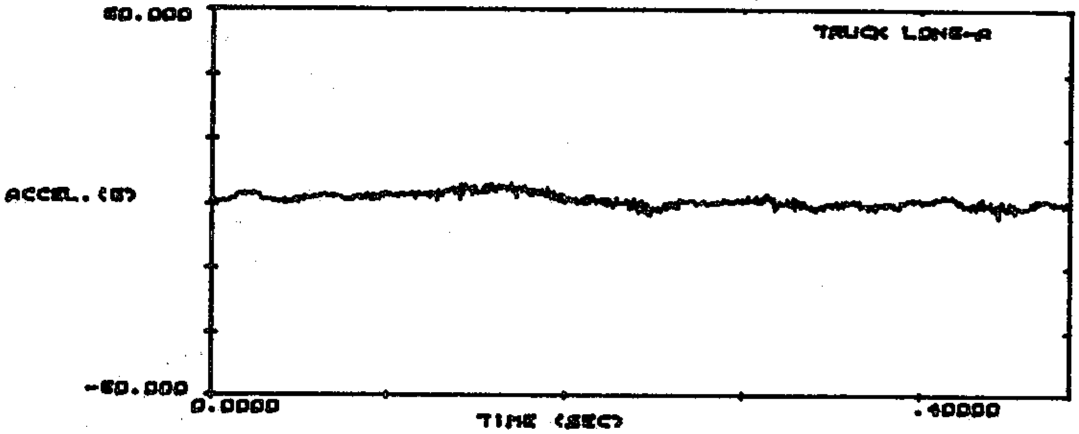
FIGURE C25 - TEST 386

TEST NUMBER
386.00
TRUCK
MOUNTED
ATTENUATOR
JUNE 11 1981

MAX. 50 MS
AVER. ACCEL.
FOR TRUCK(G)

LONGITUDINAL
4.3189
FROM TIME(S)
.13150

LONGITUDINAL
3.8626
FROM TIME(S)
.13600



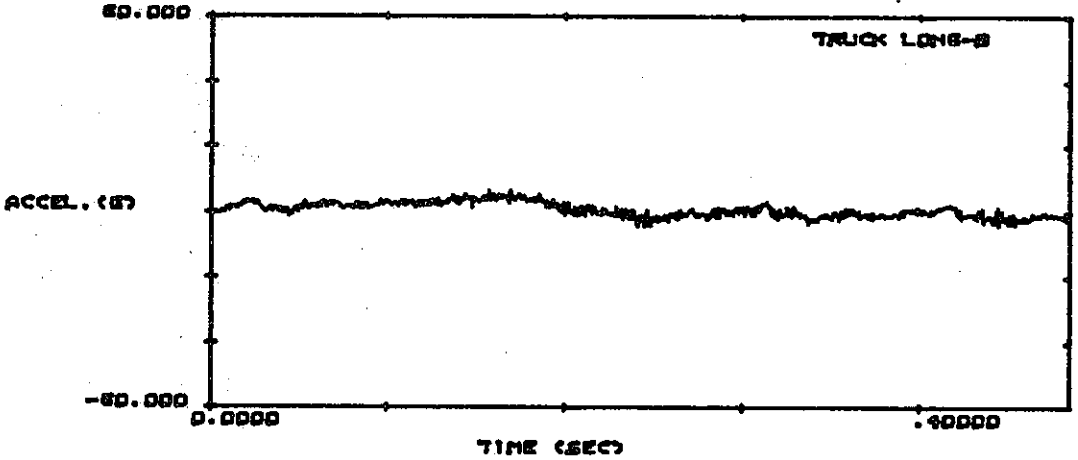


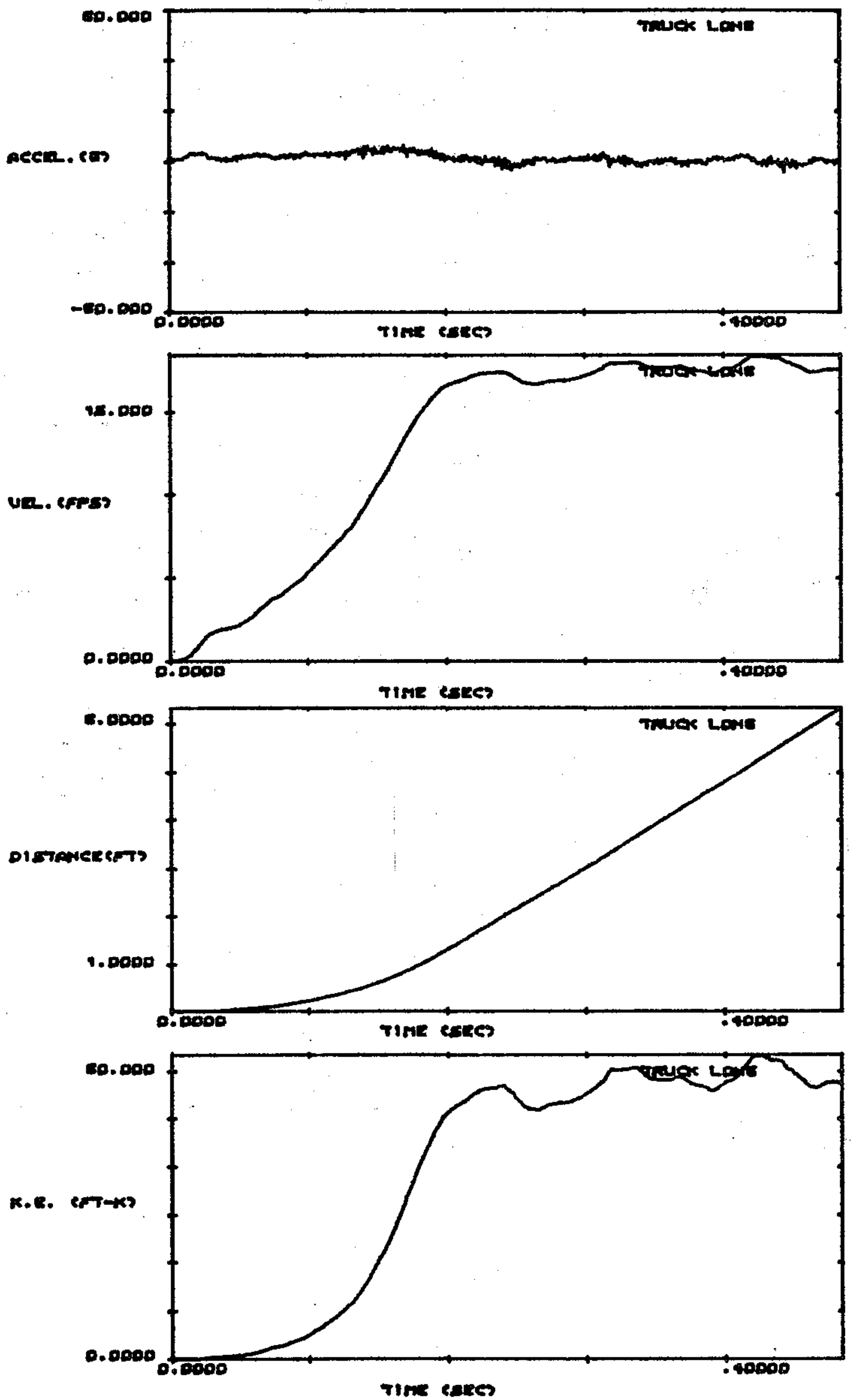
FIGURE C26 - TEST 386

TEST NUMBER
386.00
TRUCK
MOUNTED
ATTENUATOR
JUNE 11 1981

TRUCK WEIGHT
(POUNDS)-
11970.
MASS(SLUGS)-
.37174

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)



TEST NUMBER
387.00
TRUCK
MOUNTED
ATTENUATOR
AUG. 11 1981

MAX. 50 MS
AVER. ACCEL.
FOR CAR (G)-

VERTICAL---
-4.6207
FROM TIME(S)
9.7000E-02

LONGITUDINAL
-14.438
FROM TIME(S)
.13250

LATERAL---
.77331
FROM TIME(S)
8.3500E-02

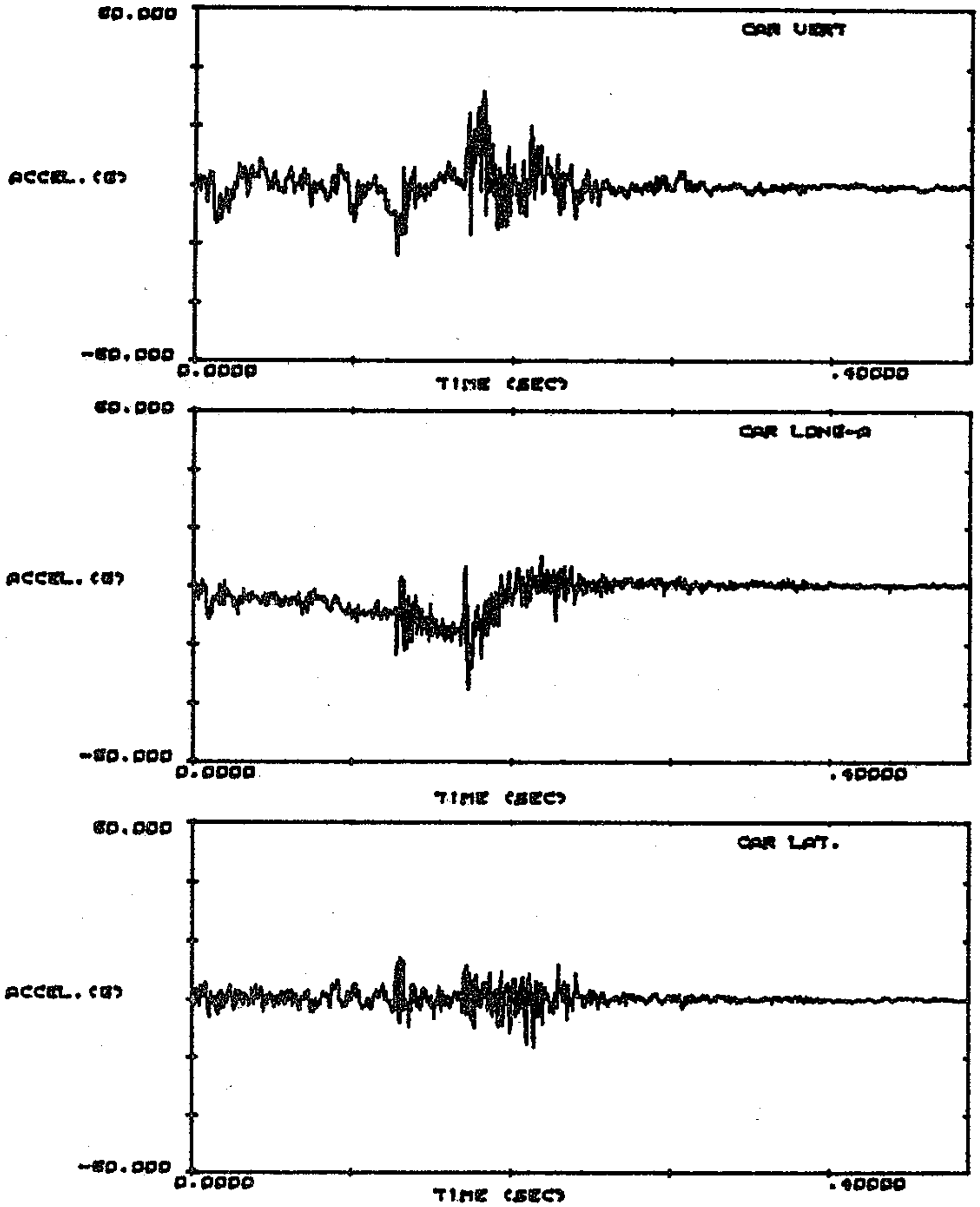


FIGURE C28 - TEST 387

TEST NUMBER
387.00
TRUCK
MOUNTED
ATTENUATOR
AUG. 11 1981

CAR IMPACT
VELOCITY
(FPS)-
66.666

AT CAR
DISTANCE(FT)
8.1995
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
34.466
OCCURS AT
.15300
SEC. AFTER
CAR IMPACT

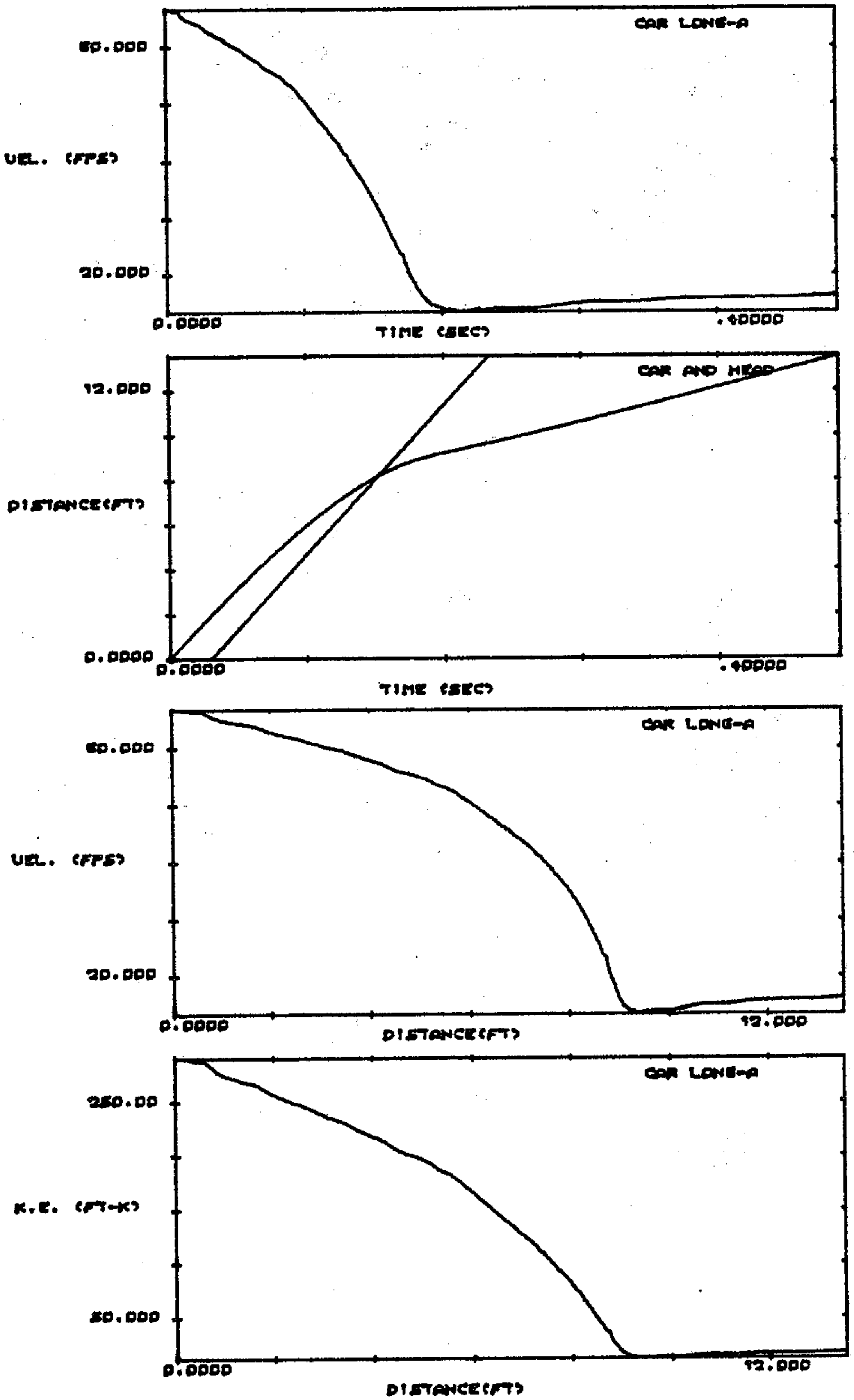
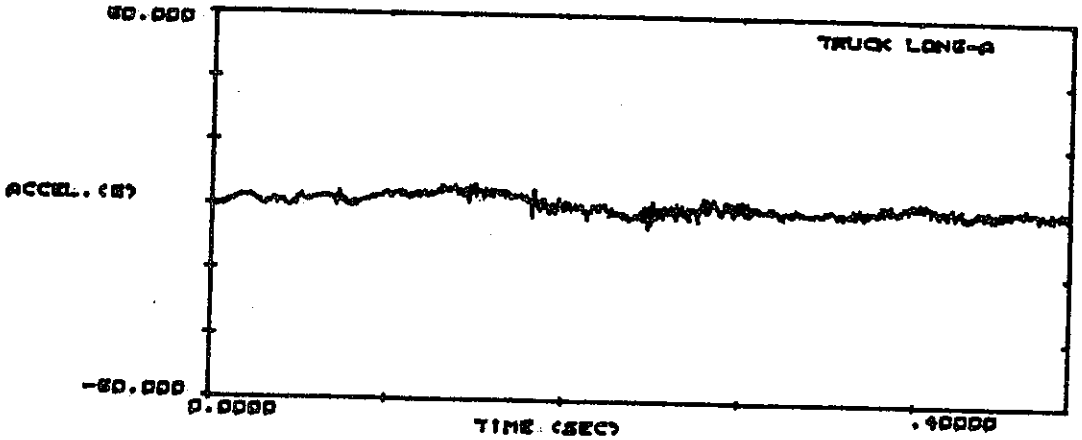


FIGURE C29 - TEST 387

TEST NUMBER
387.00
TRUCK
MOUNTED
ATTENUATOR
AUG. 11 1981

MAX. 50 MS
AVER. ACCEL.
FOR TRUCK(G)

LONGITUDINAL
4.3331
FROM TIME(S)
.11900

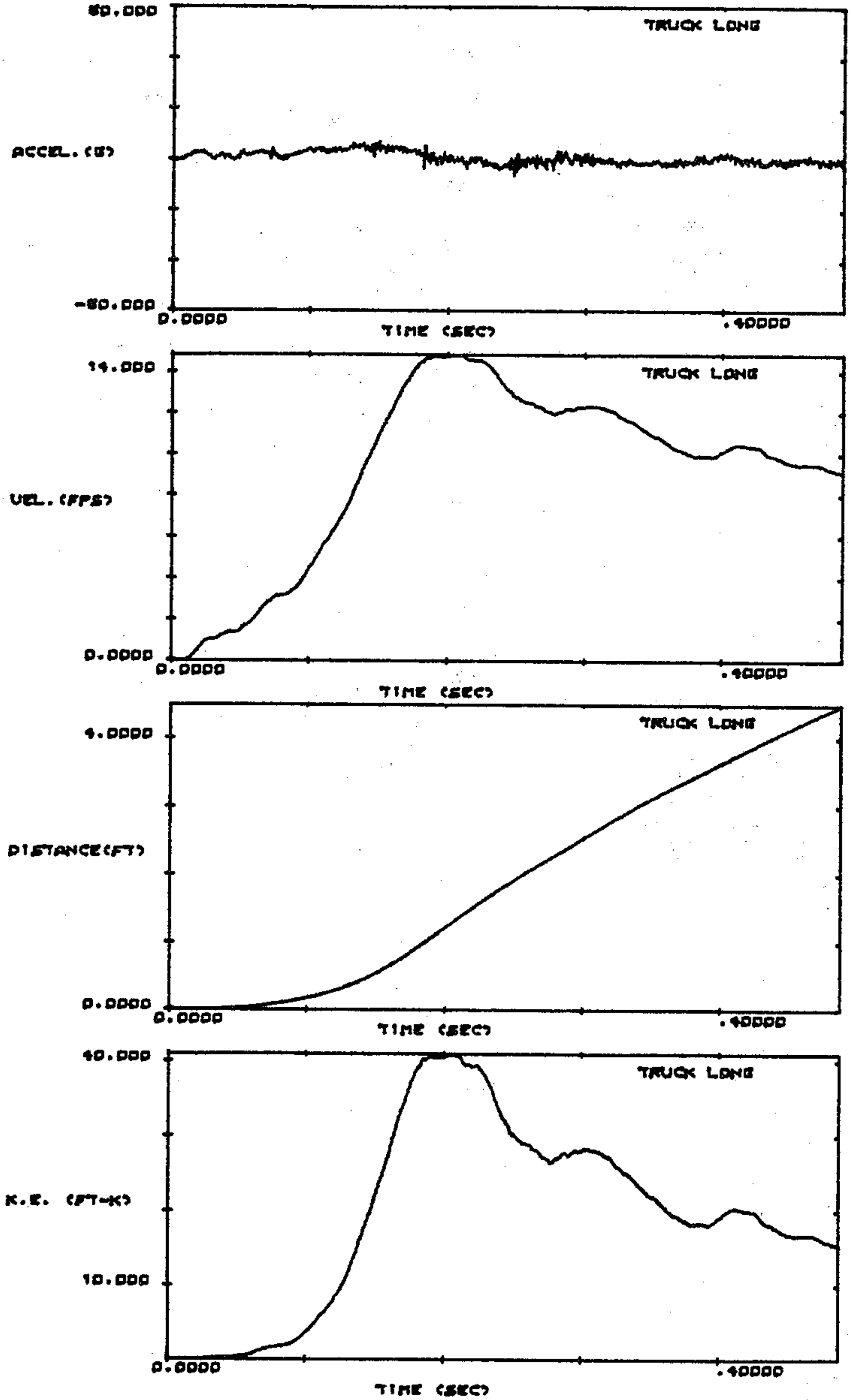


TEST NUMBER
387.00
TRUCK
MOUNTED
ATTENUATOR
AUG. 11 1981

TRUCK WEIGHT
(POUNDS)-
11970.
MASS(SLUGS)-
.37174

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)



TEST NUMBER
388.00
TRUCK
MOUNTED
ATTENUATOR
AUG. 27 1981

MAX. 50 MS
AVER. ACCEL.
FOR CAR (G)-

VERTICAL---
-5.1717
FROM TIME(S)
8.0000E-02

LONGITUDINAL
-13.826
FROM TIME(S)
.12900

LONGITUDINAL
-13.756
FROM TIME(S)
.12900

LATERAL---
.57475
FROM TIME(S)
8.0500E-02

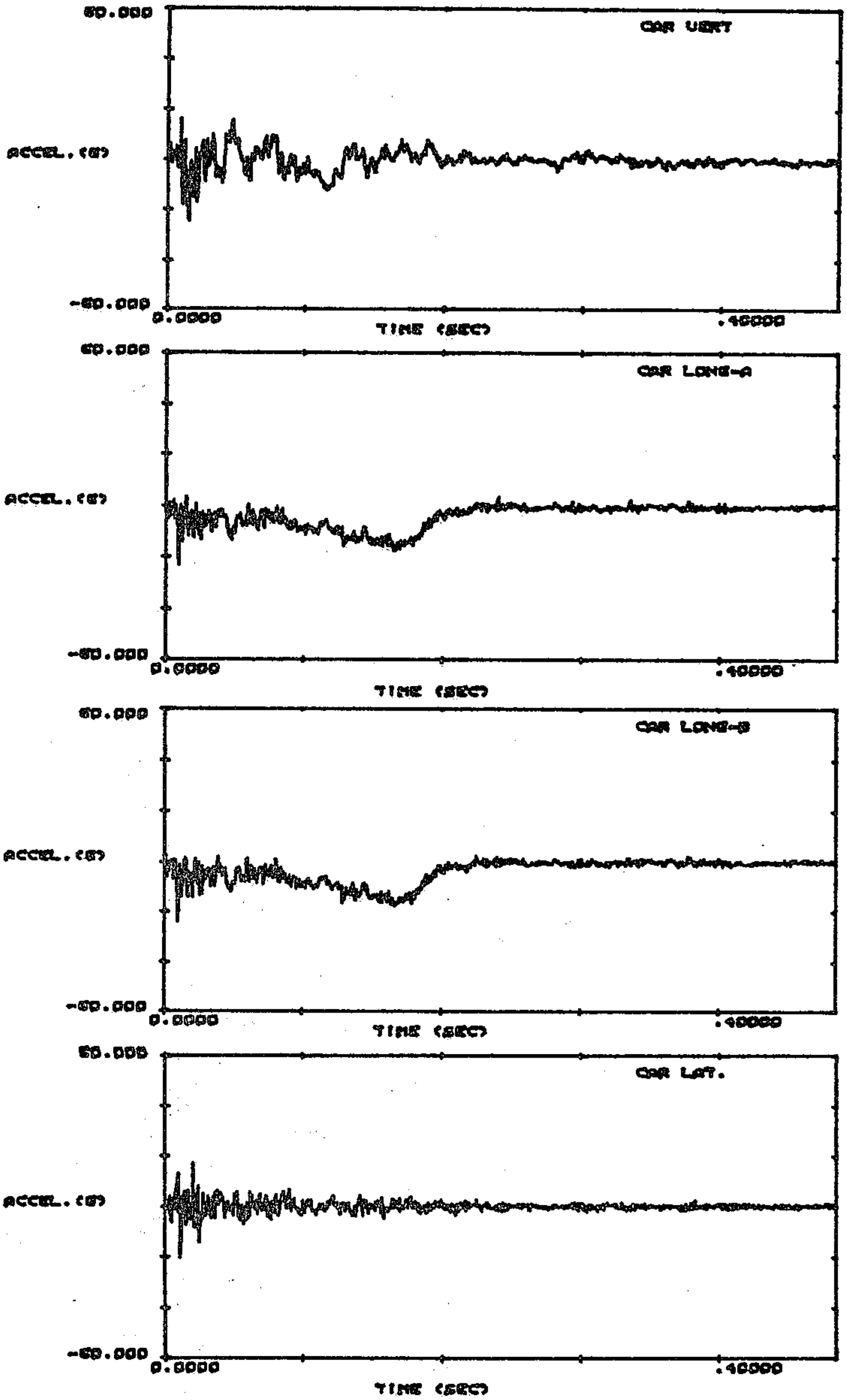


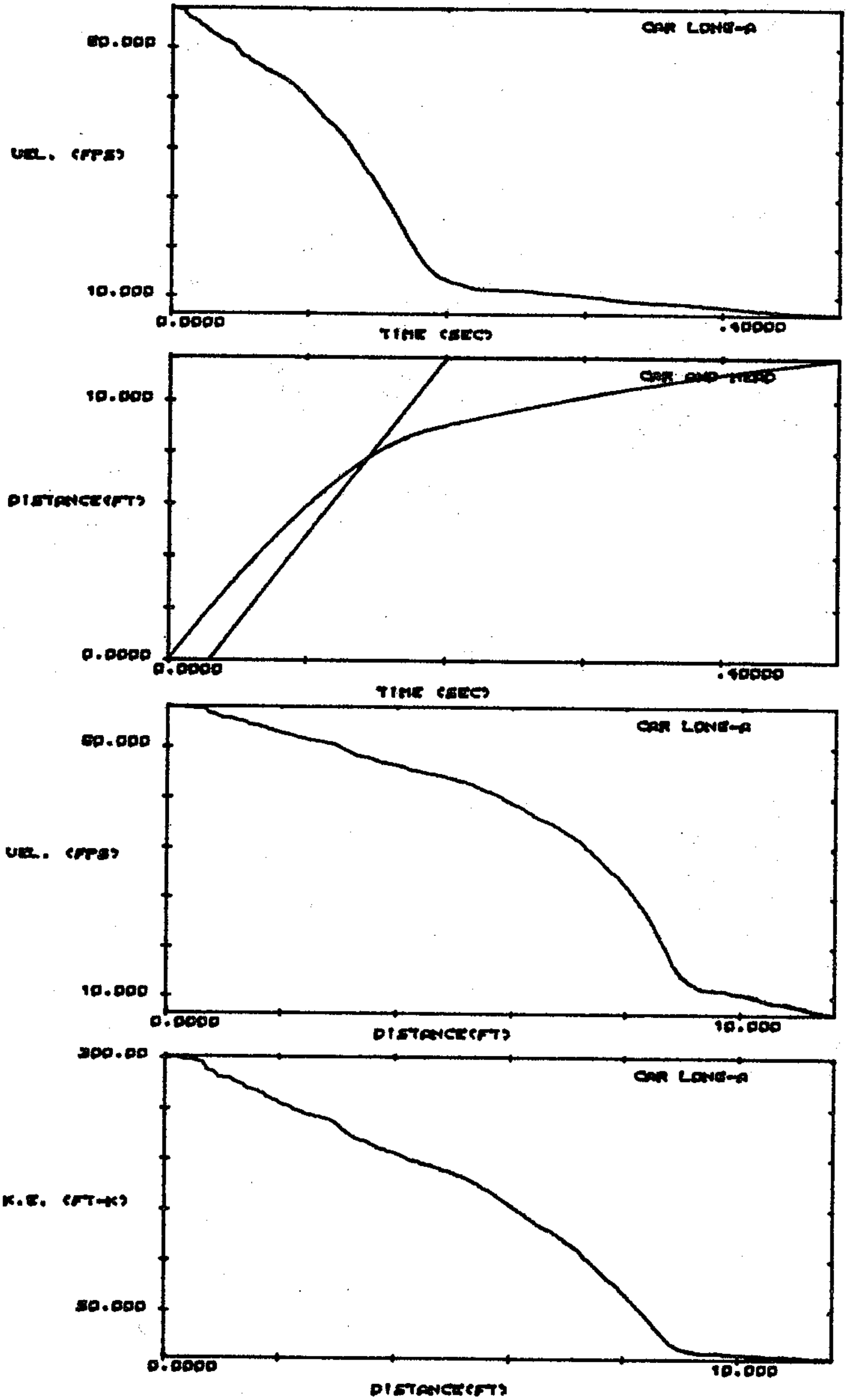
FIGURE C32 - TEST 388

TEST NUMBER
388.00
TRUCK
MOUNTED
ATTENUATOR
AUG. 27 1981

CAR IMPACT
VELOCITY
(FPS)-
67.989

AT CAR
DISTANCE(FT)
7.7914
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
33.337
OCCURS AT
.14400
SEC. AFTER
CAR IMPACT



TEST NUMBER
388.00
TRUCK
MOUNTED
ATTENUATOR
AUG. 27 1981

MAX. 50 MS
AVER. ACCEL.
FOR TRUCK(G)

LONGITUDINAL
4.4184
FROM TIME(S)
.12750

LONGITUDINAL
4.1752
FROM TIME(S)
.12800

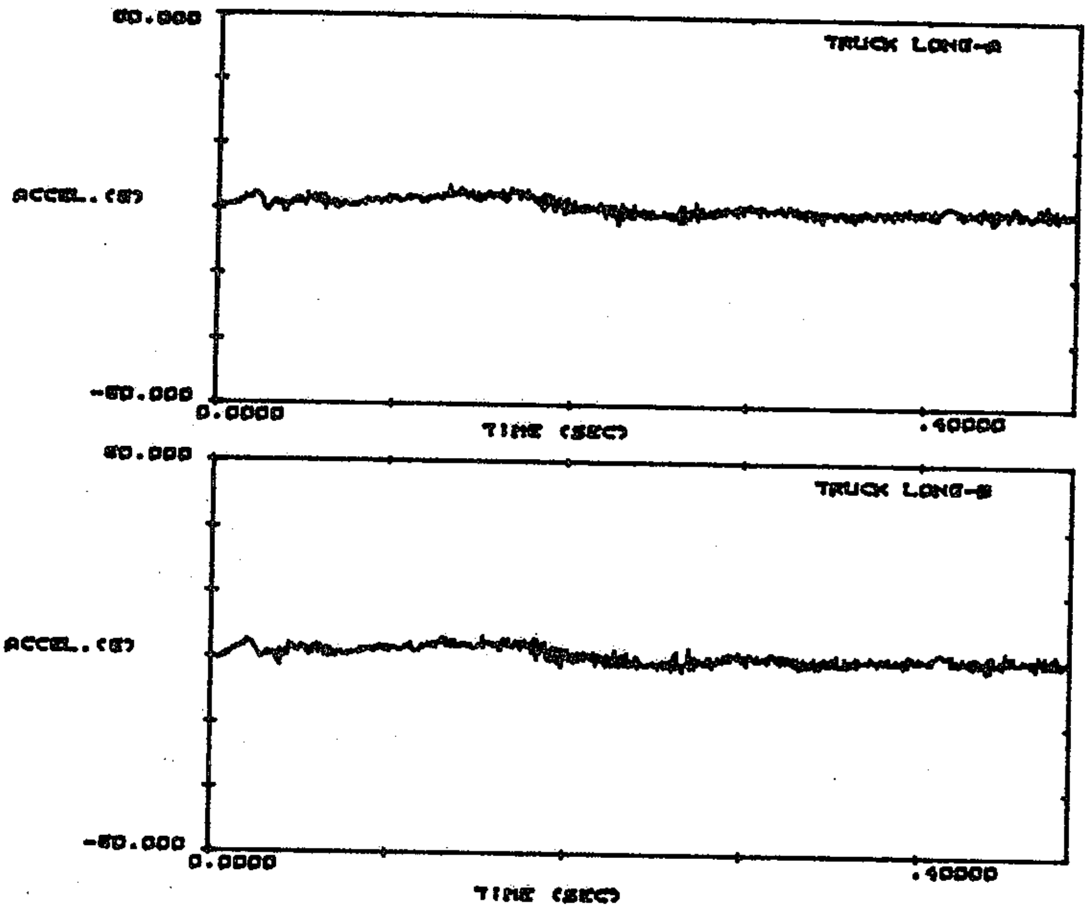


FIGURE C34 - TEST 388

TEST NUMBER
388.00
TRUCK
MOUNTED
ATTENUATOR
AUG. 27 1981

TRUCK WEIGHT
(POUNDS)-
11970.
MASS(SLUGS)-
.37174

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)

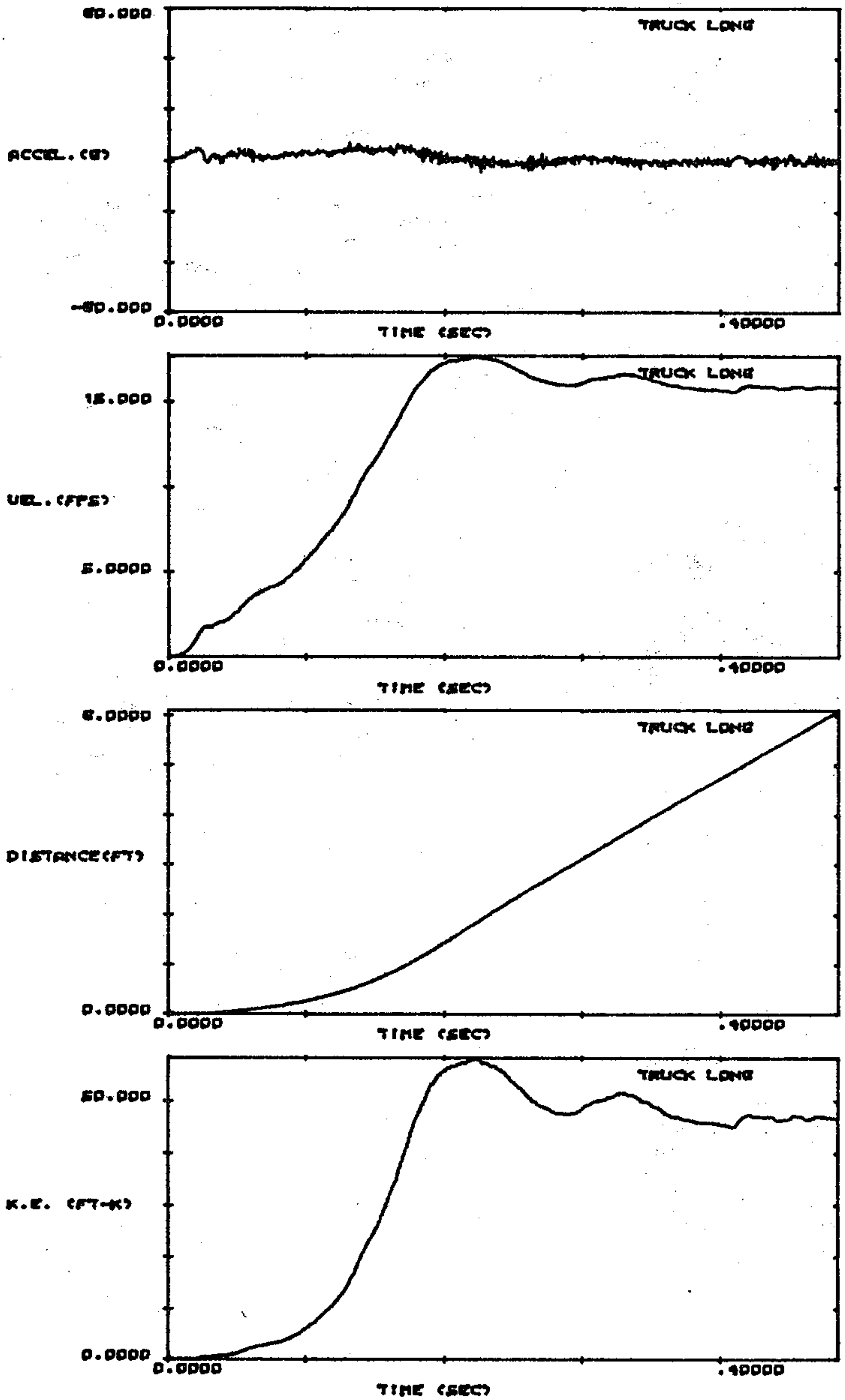


FIGURE C35 - TEST 389

TEST NUMBER

389.00

TRUCK

MOUNTED

ATTENUATOR

SEPT 24 1981

MAX. 50 MS

AVER. ACCEL.

FOR CAR (G)-

VERTICAL---

4.6449

FROM TIME(S)

.17750

LONGITUDINAL

-10.160

FROM TIME(S)

.14900

LONGITUDINAL

-10.955

FROM TIME(S)

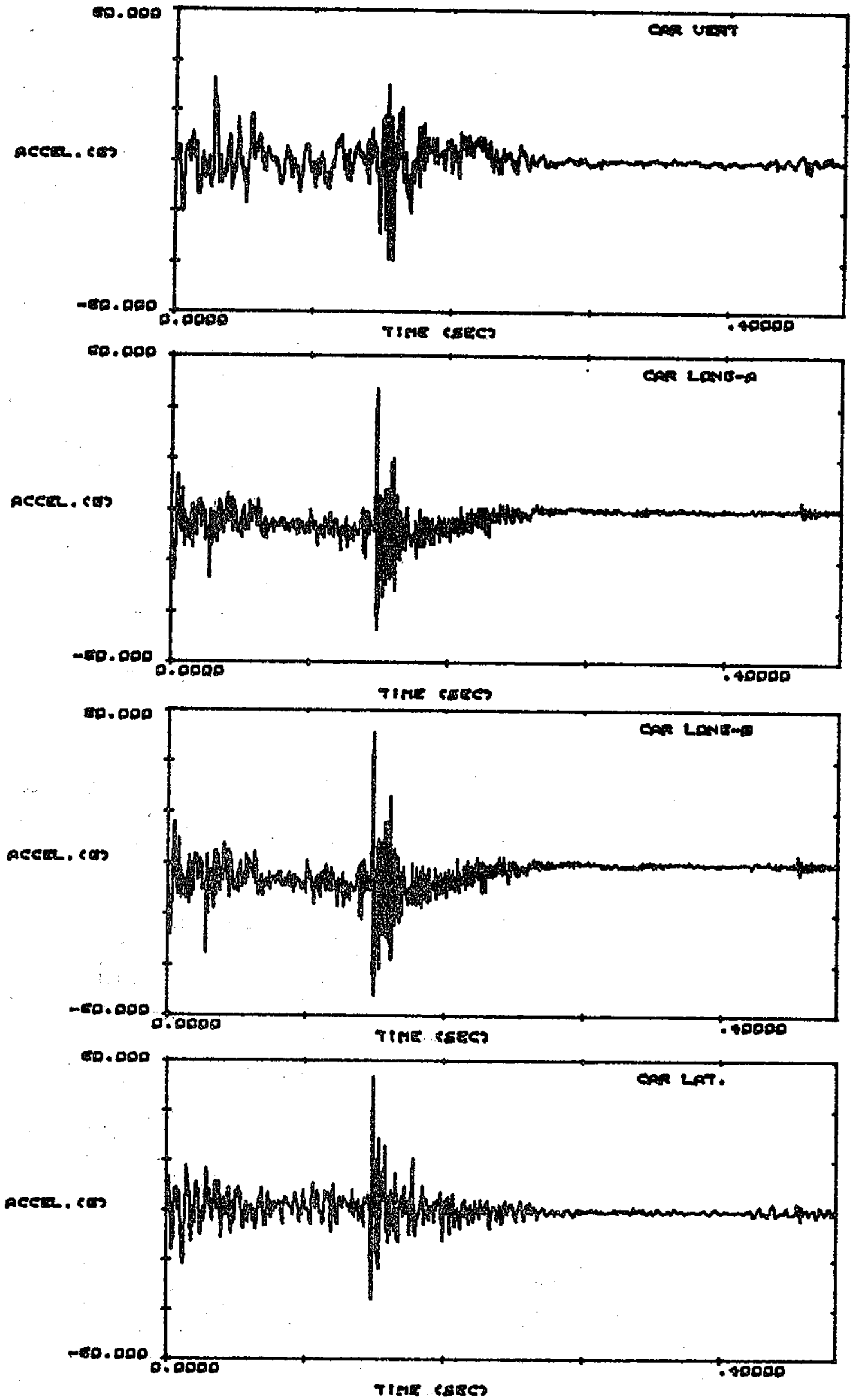
.14900

LATERAL---

2.3887

FROM TIME(S)

.10850

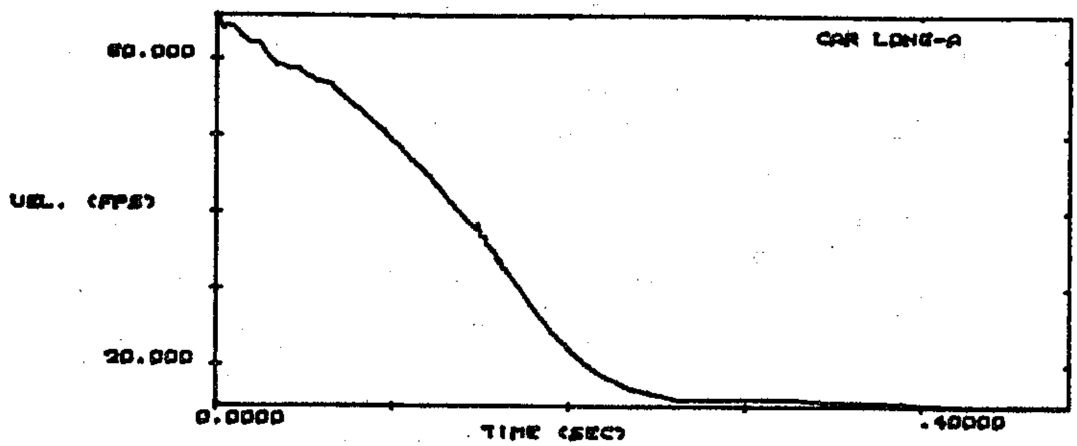


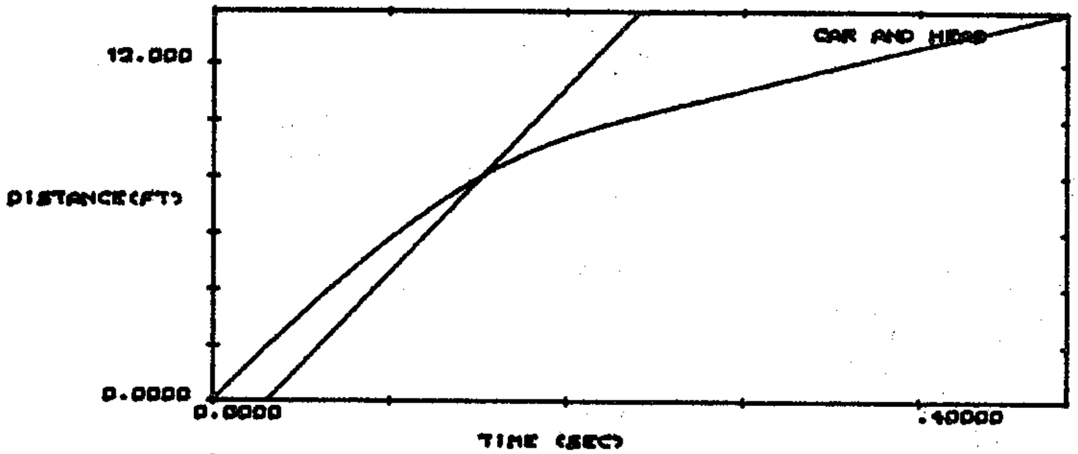
TEST NUMBER
389.00
TRUCK
MOUNTED
ATTENUATOR
SEPT 24 1981

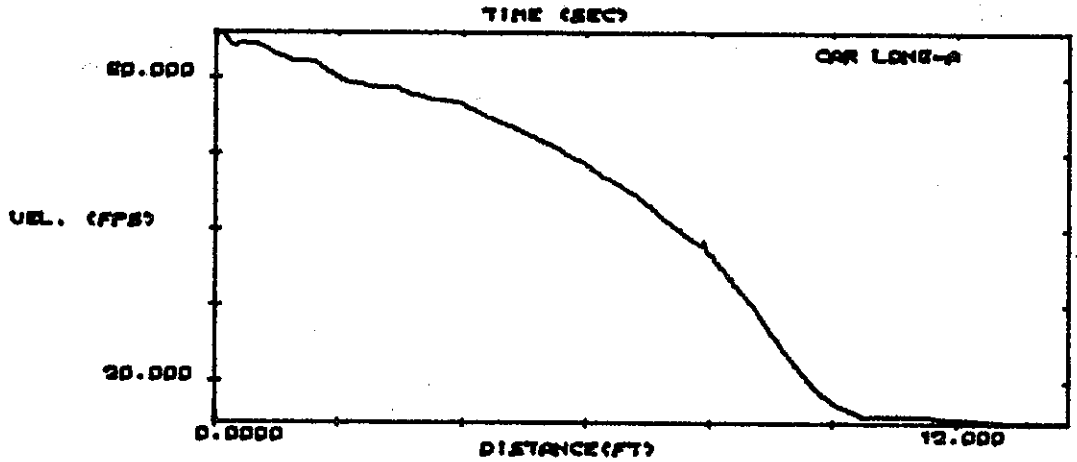
CAR IMPACT
VELOCITY
(FPS)-
65.754

AT CAR
DISTANCE(FT)
8.0598
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
29.145
OCCURS AT
.15300
SEC. AFTER
CAR IMPACT







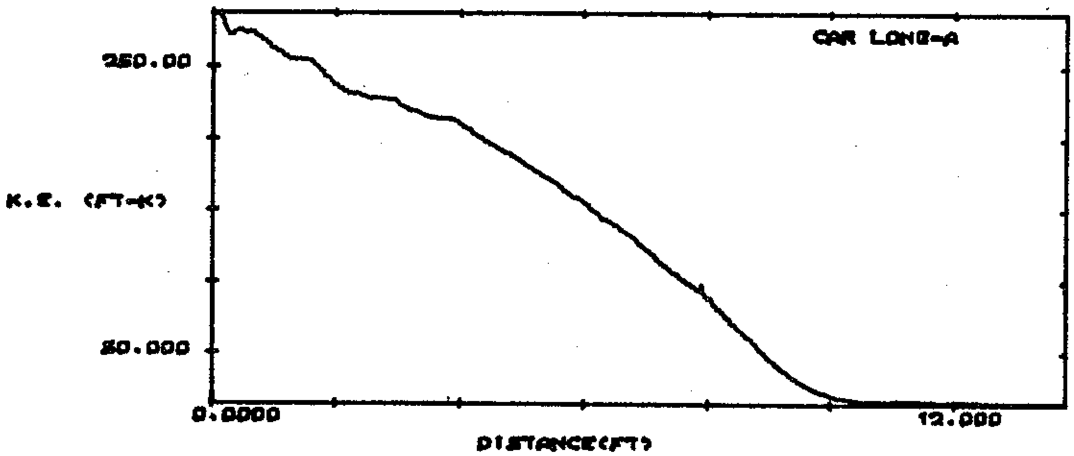


FIGURE C37 - TEST 392

TEST NUMBER
392.00
TRUCK
MOUNTED
ATTENUATOR
JUNE 9 1982

MAX. 50 MS
AVER. ACCEL.
FOR CAR (G)-

VERTICAL---
2.1332
FROM TIME(S)
2.2800E-02

LONGITUDINAL
-6.3160
FROM TIME(S)
2.2700E-02

LATERAL---
-.45028
FROM TIME(S)
6.1000E-03

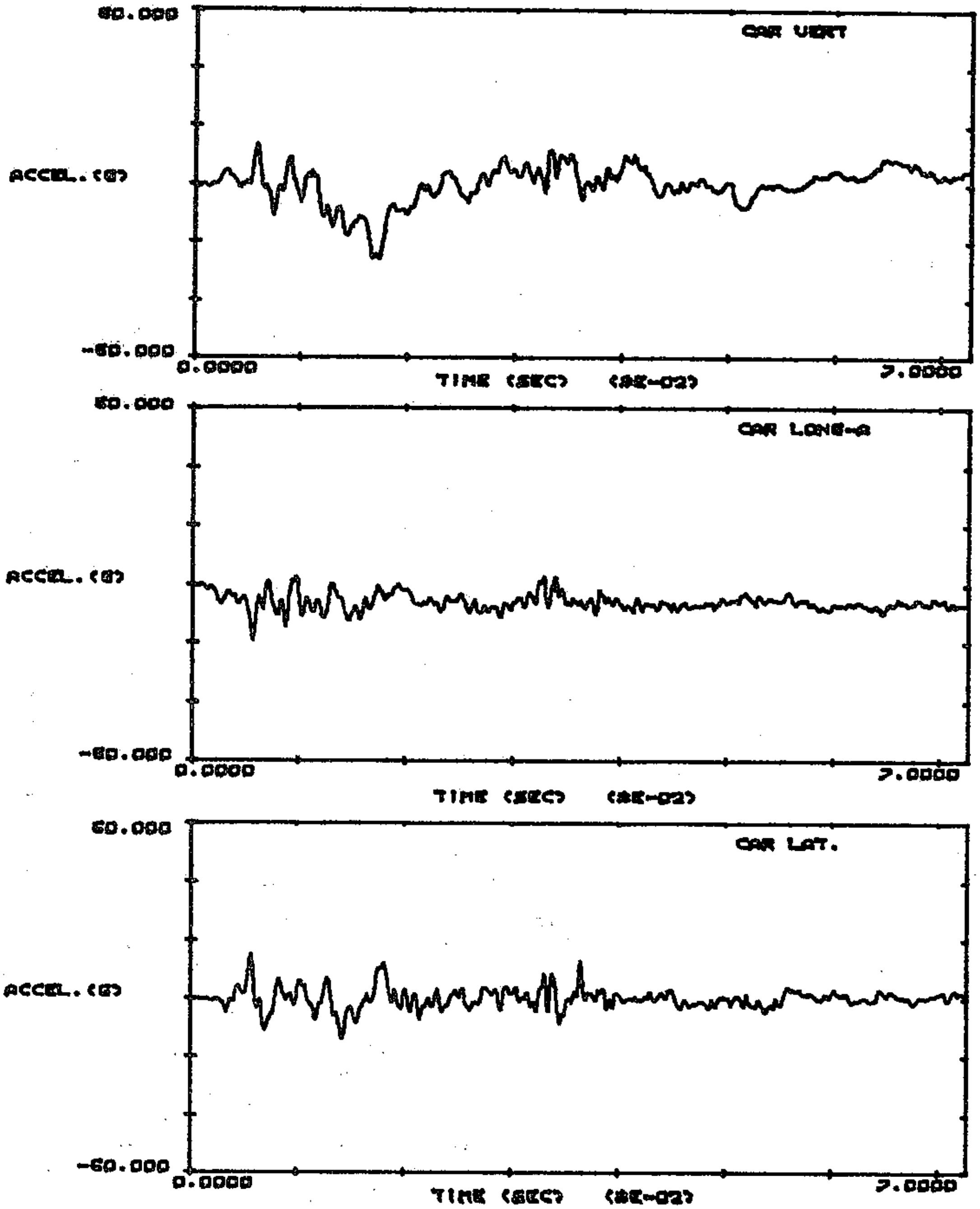


FIGURE C38 - TEST 392

TEST NUMBER

392.00

TRUCK

MOUNTED

ATTENUATOR

JUNE 9 1982

MAX. 50 MS

AVER. ACCEL.

FOR TRUCK(G)

LONGITUDINAL

7.7431

FROM TIME(S)

8.8000E-02

LATERAL---

.81716

FROM TIME(S)

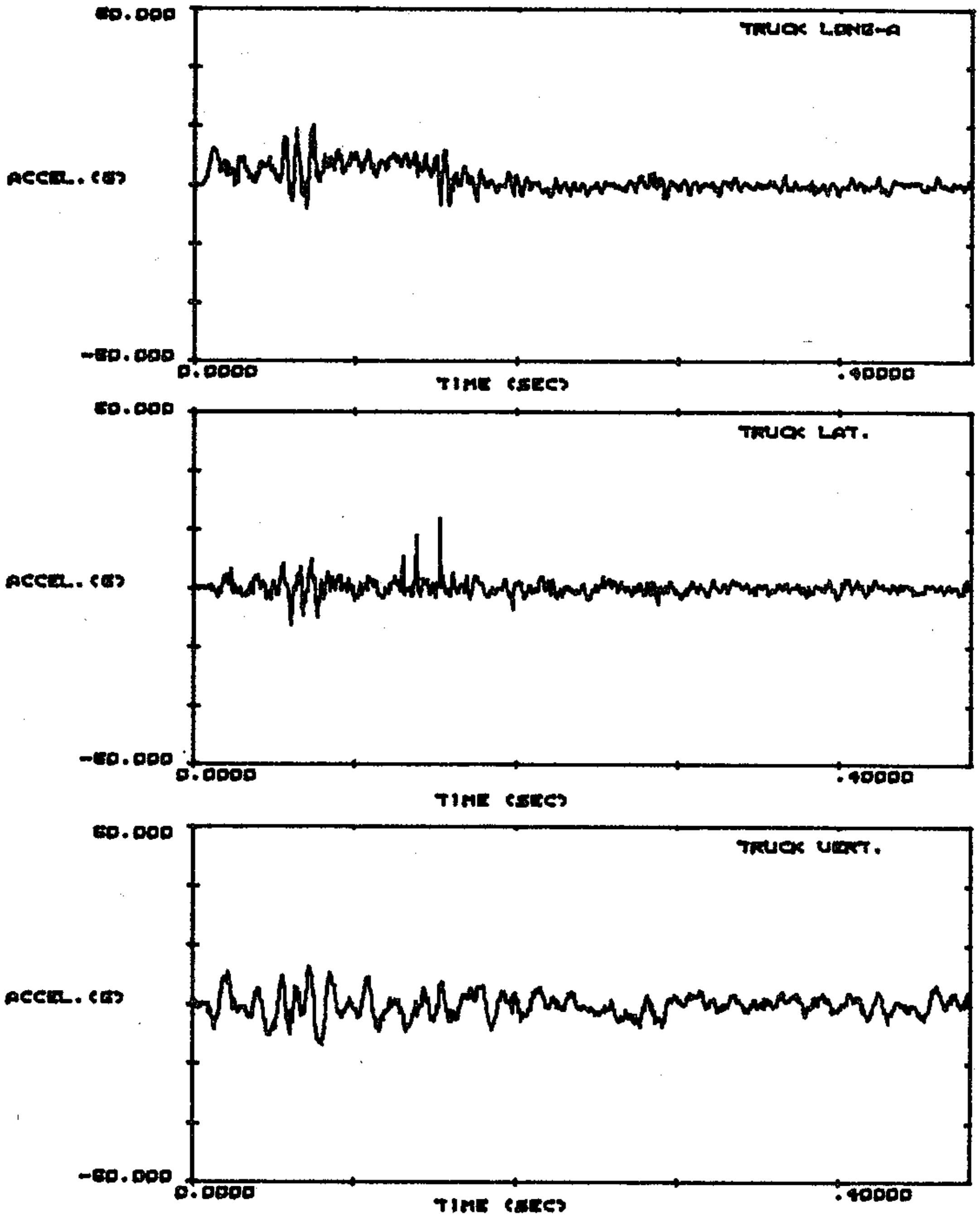
.13000

VERTICAL--

-3.0545

FROM TIME(S)

.24350



TEST NUMBER
392.00
TRUCK
MOUNTED
ATTENUATOR
JUNE 9 1982

TRUCK WEIGHT
(POUNDS)-
5000.0
MASS(SLUGS)-
.15528

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)

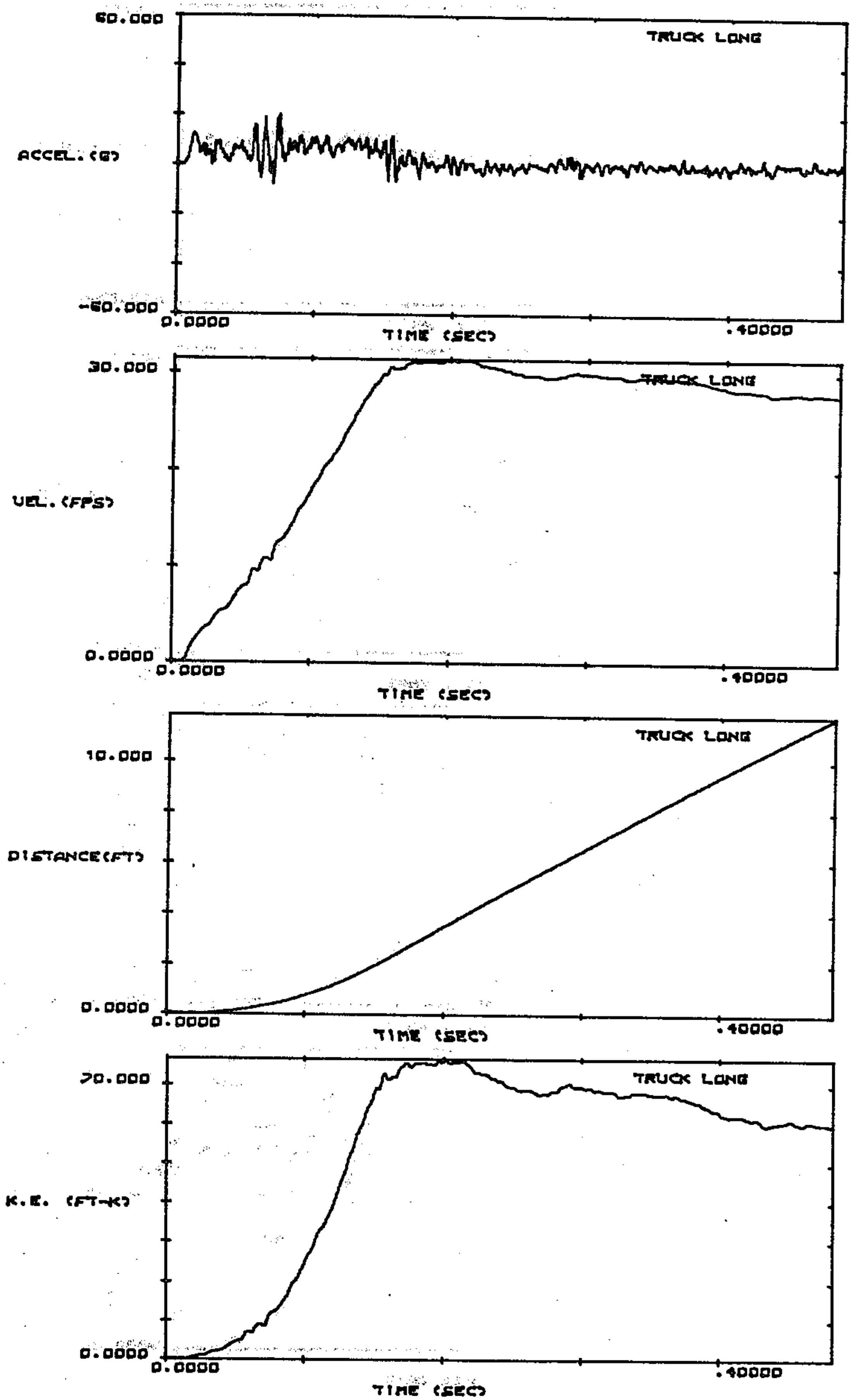


FIGURE C40 - TEST 393

TEST NUMBER

393.00

TRUCK

MOUNTED

ATTENUATOR

SEPT 15 1982

MAX. 50 MS

AVER. ACCEL.

FOR CAR (G)-

VERTICAL---

-1.3082

FROM TIME(S)

2.3500E-02

LONGITUDINAL

-12.408

FROM TIME(S)

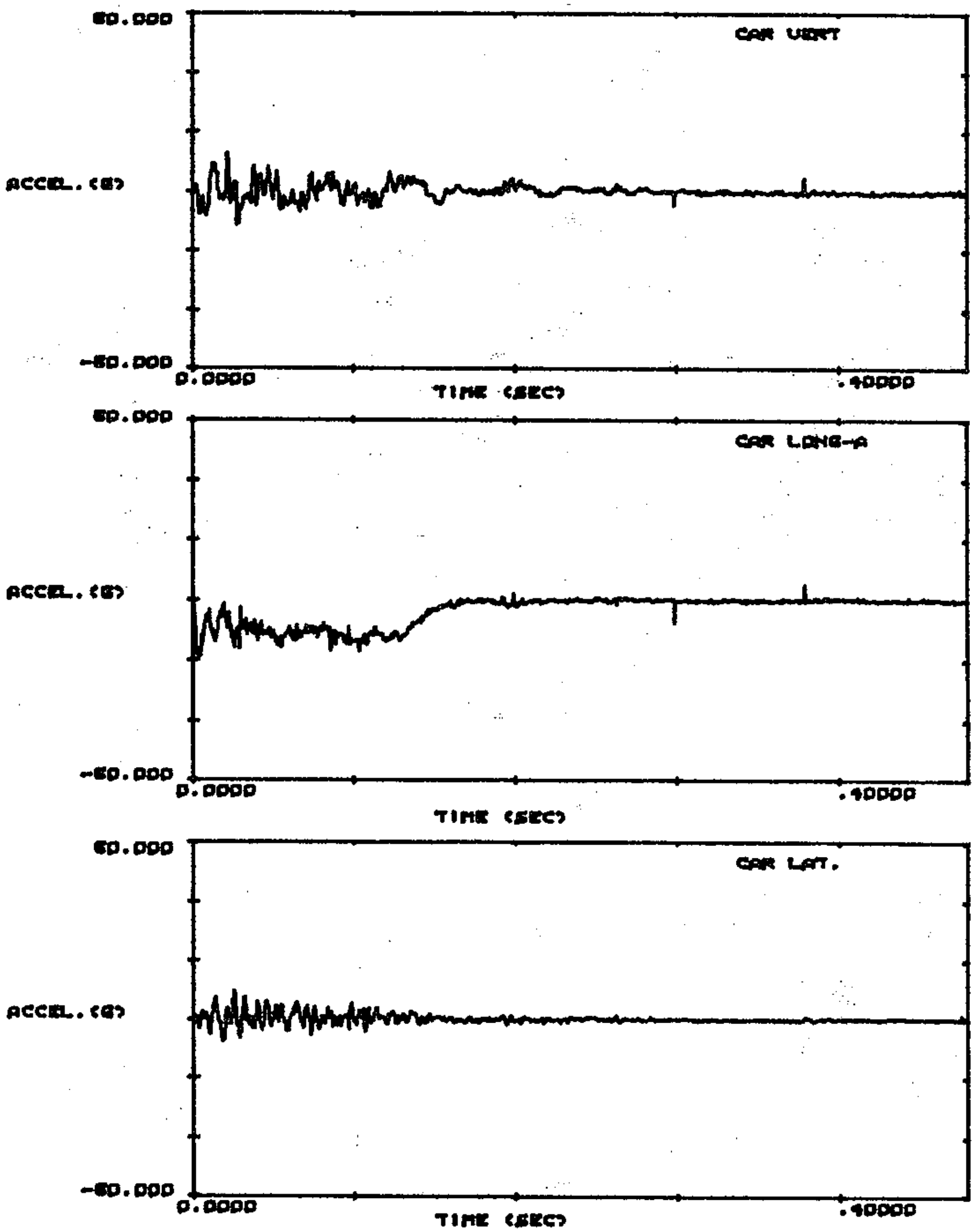
8.4000E-02

LATERAL

.81847

FROM TIME(S)

2.1500E-02



TEST NUMBER
393.00
TRUCK
MOUNTED
ATTENUATOR
SEPT 15 1982

CAR IMPACT
VELOCITY
(FPS)-
65.707

AT CAR
DISTANCE(FT)
5.2923
OCCUPANT
IMPACT
OCCURS

OCCUPANT
IMPACT
VELOCITY
(FPS)-
38.972
OCCURS AT
.11100
SEC. AFTER
CAR IMPACT

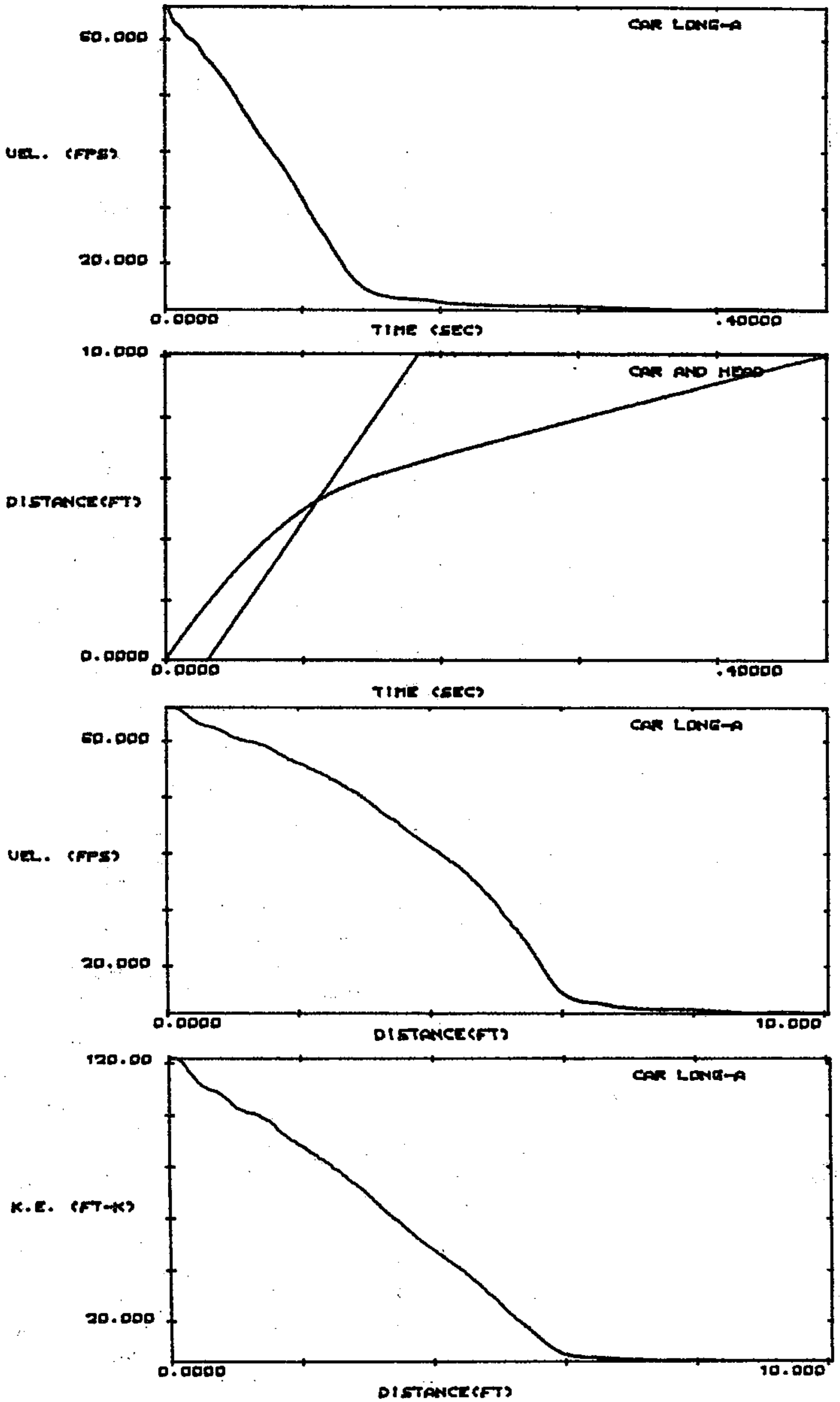


FIGURE C42 - TEST 393

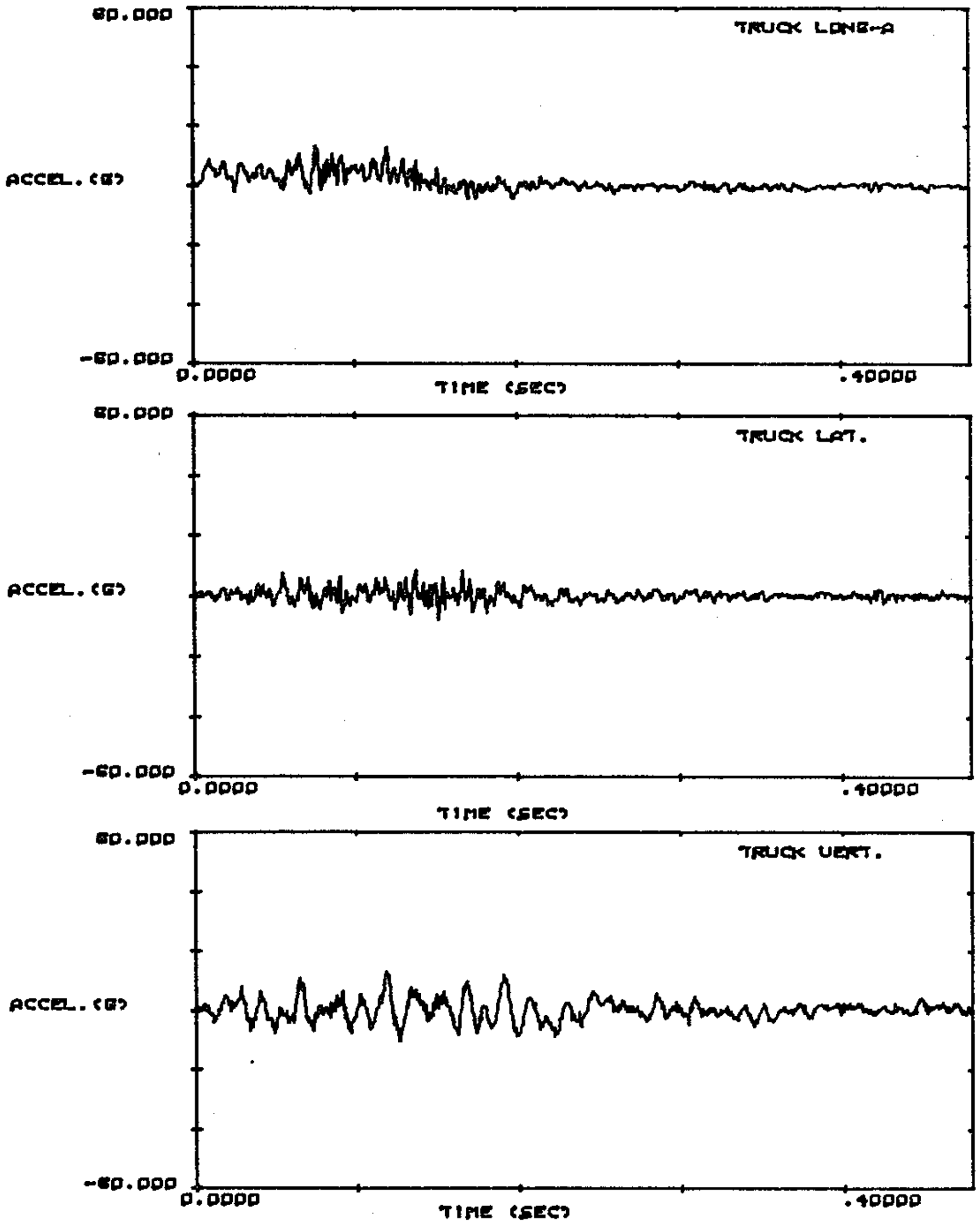
TEST NUMBER
393.00
TRUCK
MOUNTED
ATTENUATOR
SEPT 15 1982

MAX. 50 MS
AVER. ACCEL.
FOR TRUCK(G)

LONGITUDINAL
5.4231
FROM TIME(S)
7.5500E-02

LATERAL
1.0176
FROM TIME(S)
.10100

VERTICAL--
-2.1980
FROM TIME(S)
.19400

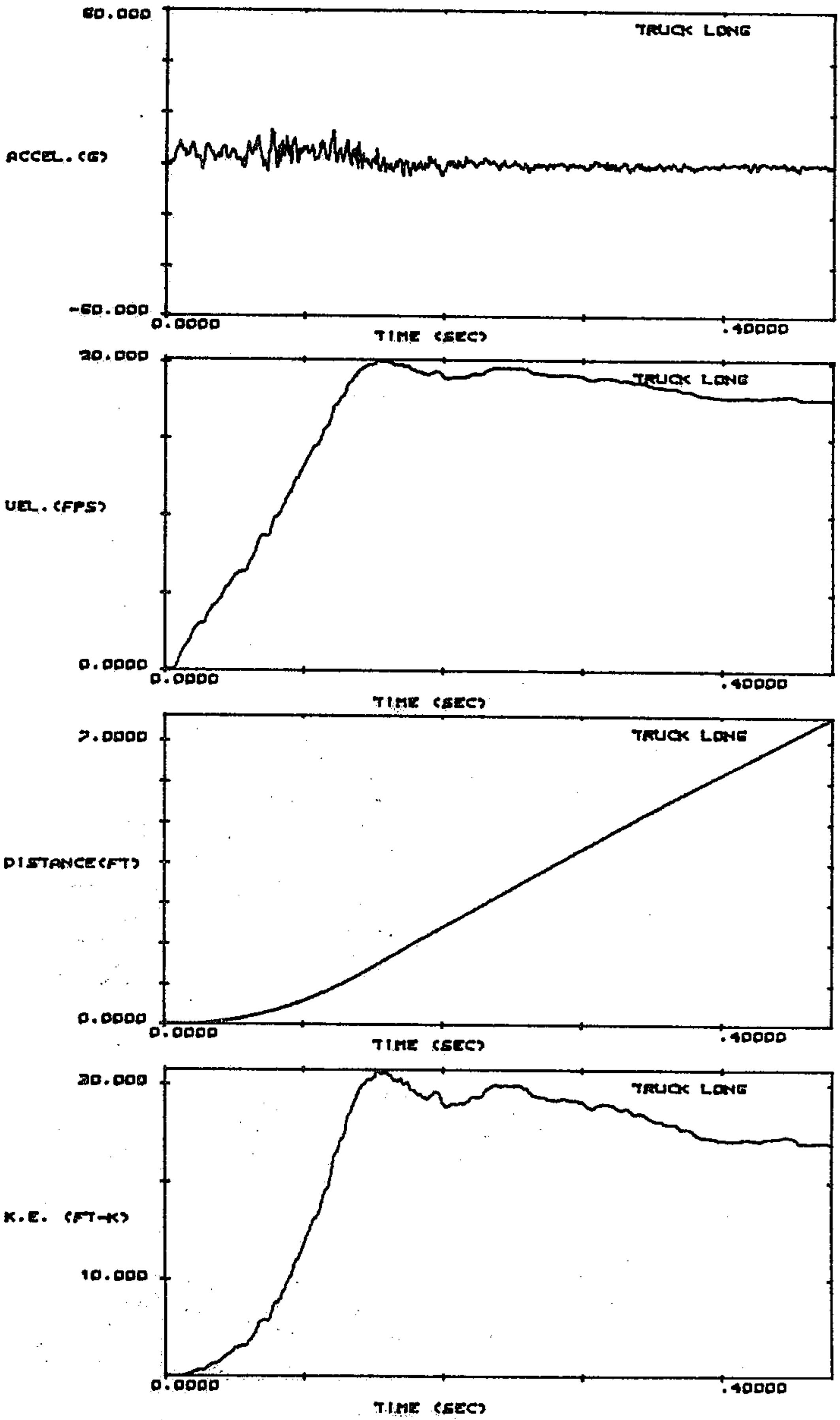


TEST NUMBER
393.00
TRUCK
MOUNTED
ATTENUATOR
SEPT 15 1982

TRUCK WEIGHT
(POUNDS)-
5000.0
MASS(SLUGS)-
.15528

KINETIC
ENERGY (KE)
EQUALS 1/2
MASS TIMES
THE SQUARE
OF THE VEL.

AT IMPACT
VELOCITY
IS ZERO
(THEREFORE
KINETIC
ENERGY
IS ZERO)



APPENDIX D: ACCIDENT EXPERIENCE

Rear End Accidents Involving Caltrans Vehicles January 1, 1983 through October 6, 1983

Detailed data was tabulated on all impacts into Caltrans vehicles in 1983. The data was taken from accident records, with added data from the districts, and compiled by the Departmental Safety Branch in the Caltrans Division of Administrative Services. Table D.2 condenses some of that information for all rear end impacts. The purpose of the condensed table is to show typical impact speeds, size of State and private vehicles, whether or not the Caltrans vehicle was parked, vehicle damage, and number of injury accidents. That data is analyzed in Table D.1.

It can be concluded from the data in Table D.1 that we can expect State trucks equipped with TMAs to be impacted not only by passenger cars traveling under 45 mph, but also by cars traveling faster and by heavy vehicles. Therefore, in a certain percentage of impacts the capacity of the TMA will be exceeded. Nevertheless, even in these more severe impacts, the TMA should provide some reduction in the car acceleration as compared with the case of a truck without a TMA.

Rear End Accidents Involving Caltrans TMA Trucks

Table D.2 indicates there were ten rear end accidents with TMA trucks. Two of these accidents involved TMA trucks that were equipped with TMA hardware with the TMA removed. During certain operations TMA trucks may be used for purposes that require the TMA to be removed.

There were two fatalities and two known injuries in the ten accidents. One accident resulted in a fatality and an injury to the truck driver. The truck in this accident had the TMA removed. The second fatality accident was the result of a motorcycle impacting a TMA. In the second injury accident the TMA was removed.

Table D.1 Analysis of Rear End Accident Data
January 1983 through September 1983

GENERAL:

Number of Rear End Accidents 104
Number of Rear End Accidents with TMA's. 6

PRIVATE VEHICLE (STRIKING VEHICLE)*

Vehicle Size	Total No.	Speed (mph) 0 to 45	45+	Injuries	Fatalities
Truck	11	10	1	1	
Van	5	4	1		
Pickup	23	17	4	5	
Station Wagon	4	4			
Car	38	23	5	5	2
Small Car	18	13	2	5	
Jeep	3	1	2	4	
Motorcycle	1				1
Jetney	1	1			

STATE VEHICLE (STRUCK VEHICLE)*

Vehicle Size	Total No.	Moving	Parked Occupied	Parked	Injuries	Fatalities
Pickup	22	4	13	6	1	
Dump Truck	33	15	13	4	5	
Cargo Truck	16	7	8	1	8	
Utility Truck	8	2	4	2	3	
Van	4		3	1	1	
Sweeper	2	1	1			
Tow Truck	5	1	4			
Boom Truck	3	1	2			
Cone Truck	4	1	2	1		
Paint Striper	1		1			
Fence Truck	1		1			
Landscape Truck	1		1			
Rotary Snowplow	2	2				
Loader	1		1			

* Figures are not exact due to inadequate accident data

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 1 83330	45	1972 Toyota Jeep	Front End	4 Injured	Parked	1981 IHC Dump I# 03323 C# 1409	Flap, sander hook, emulsion line, rear axle pushed forward, bent spring, collapsed drive line	None
Dist. 2 83092		1975 Kenworth Tractor	Front end, both front fenders, right side of sleeper	None	Stopped Occupied	1980 IHC 5-yd. Dump I# 03323 C# 1369	Left rear spring, left dual tires and wheels, drive line, drive line center bearing	None
Dist. 3 83001		1970 Chevrolet Pickup with Camper	Right front of camper	None	Stopped Occupied	1980 GMC Dump I# 02220 C# 2491	None	None
Dist. 3 83008	15-20	Chevrolet Camero	Major front end	None	Stopped Occupied	1978 IHC Dump I# 02921 C# 2064	Bent spinner guard	None
Dist. 3 83014	25-30	1966 Mustang	Radiator pushed back into engine	None	Stopped Occupied	1978 IHC I# 02921 C# 2064	Bent spinner guard	None
Dist. 3 83019				None	Moving	1982 Autocar I# 04721 C# 2501	Sander bar protector	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 3 83030	40	Pickup		None	Moving	1975 Mobil sweeper I# 56808 C# 3031	Left taillight cracked and bracket bent, hydraulic motor slightly dented	None
Dist. 3, 83059	5-10	1981 Chevrolet 3/4-Ton Pickup	Vehicle smashed in front and rear	None	Stopped Occupied	1974 IHC Cargo truck I# 01050 C# 3034	None	2 Injured
Dist. 3 83063	45-50	1976 Pontiac Firebird	Front end	None	Moving	1981 Mack I# 13721 C# 2631	Spinner box frame	None
Dist. 3 83065	45	Datsun Pickup	Right headlight broken, grill broken, bent bumper	None	Moving	1980 Dodge Pickup I# 00607 C# 5043	Rear bumper bent	None
Dist. 3 83108	15	1975 Toyota	Right front headlight area	None	Stopped Occupied	1980 Jeep 4-WD pickup I# 10831 C# 4595	Rear bumper bent, bed loose, dent in right rear corner of cab	None
Dist. 3 83136		1978 Oldsmobile	Left rear fender and taillight rear bumper, trunk	None	Moving	1980 IHC Sweeper shadow truck	None	None
Dist. 3 83137	25	1972 Dodge Van	Front - moderate	None	Stopped Occupied	1981 IHC I# 03321 C# 2123	Bent guard around spreader unit	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 4 83005	45	1976 Oldsmobile Delta 88	Major front end	1 Fatality	Moving	1972 IHC Dump I# 01820 C# 0329 Sweeper shadow truck	Attenuator hoses sheared off, running lights broken, "sweeper ahead" sign damaged	1 Injured
Dist. 4 83007		1970 Plymouth	Total front (grill, radiator, fenders)	None	Stopped	1971 Ford Tow truck I# 02591 C# 8734	Nil	None
Dist. 4 83023	3	1981 Toyota Tercel	Minor dent of right rear door	None	Stopped Occupied	1981 IHC Tree trimmer I# 0382 C# 1750	Nil	None
Dist. 4 83027		1980 Cadillac Eldorado		None	Stopped Occupied	1980 GMC Ladder I# 01835 C# 1732	110-volt outlet damaged, small dent on right rear bumper	None
Dist. 4 83029	10-12	Ford Courier	Right front fender peeled back to door	None	Parked Occupied	1971 IHC Cone truck I# 01037 C# 2361 Barrier vehicle	Left rear body damage. Broken reflector and clearance lamp. Broken weld at right rear of bumper. Bent taillight shroud	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

PRIVATE VEHICLE						STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 4 83058		1973 Chevrolet	Front end damage, windshield	None	Parked	1979 Dodge 3/4-Ton Utility Body	Rear bumper, tailgate, right rear fender pushed. Right rear taillight crushed. Dent behind cab	None
Dist. 4 83069	10	Jitney	None	None	Stopped Occupied	1975 Dodge 6-Passenger Pickup I# 00804 C# 3475	Right rear bumper pushed in. Small dent in tailgate.	None
Dist. 4 83070				None	Parked Occupied	1980 Dodge 1/2-Ton Pickup I# 00607 C# 4101	None	None
Dist. 4 83080		1978 Pontiac Firebird	Front bumper, grill, both front fenders	None	Stopped Occupied	1978 Dodge Utility Body I# 00830 C# 3920	Bent rear bumper	1 Injured
Dist. 4 83084		1977 Ford LTD	Major front end damage	None	Moving	1980 Dodge Utility Body I# 00830 C# 4528	Rear end damage	1 Injured
Dist. 4 83113		1960 VW Bug	Front end damaged	1 Injured	Stopped Occupied	Dodge Utility Body I# 00830 C# 2067	Left rear corner of bumper and body pushed in	1 Injured

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 4 83123		1960 Volvo	Major front end damage to the front bumper, grill, hood and left front fender	1 Injured	Parked	1977 Chevrolet 3/4-Ton Pickup I# 00807 C# 3628	Moderate right rear damage. Right rear bumper bent to right rear spring shackle. Tailgate damaged.	None
Dist. 4 83135	30	1967 VW Beetle	Front windshield	None	Parked Occupied	1973 Ford Paint Striper I# 03884 C# 0438	Nil	None
Dist. 4 83136		1978 Chevrolet Monza	Front grill, a little damage	None	Stopped Occupied	1979 Dodge Pickup I# ______ C# 3751	Rear bumper bent	None
Dist. 4 83161	55-60	1970 Rover	Right side two doors and both side panels	None	Moving	1972 IHC Dump I# 01820 C# 0336	Damage to shoveling apron and mounting tubes for shoveling apron	1 Injured
Dist. 4 83164		1980 Ford	Total damage to entire left side	1 Injured	Parked	1975 Ford Cone truck I# 01037 C# 3544	Right rear quarter panel, rear bumper, sign holder area, storage locker	None
Dist. 4 83169	5-10	1970 VW Fast Back	Front sheet metal and lights	None	Stopped Occupied	1978 Dodge Pickup I# 00607 C# 3758	Nil	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 4 83176	25	1975 Oldsmobile	Front left fender, grill	1 Injured	Parked	1975 Dodge Pickup I# 00607 C# 3380	Bumper damaged, tailgate dented	None
Dist. 4 83180				1 Injured	Stopped Occupied	1964 IHC Dump I# 01810 C# 0768	Minor damage to shoveling apron	3 Injured
Dist. 4 83188	10	1978 Oldsmobile Wagon	Extensive - right front quadrant	None	Stopped Occupied	1980 Dodge Pickup I# 00607 C# 4129	Small dent in rear left quarter panel	None
Dist. 4 83204		1982 Buick	Front end demolished	1 Injured	Moving	1977 IHC Tow Truck I# 02991 C# 2063	Extensive damage right rear side	None
Dist. 4 83212	10-15	1975 Chevrolet Pickup	Minor damage to hood, fender, grill	None	Backing	1963 IHC Tow Truck I# 02491 C# 4564	Left rear corner of tow bed including hoist controls and lower right work light	None
Dist. 4 83214		1972 Oldsmobile 98	Right front fender dented	None	Stopped Occupied	1981 IHC Tow Truck I# 02491 C# 2709	None	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE				STATE VEHICLE			
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 4 83222		1973 Ford Van	Left front fender and headlight	None	Stopped Occupied	1978 Dodge Utility Body I# 00830 C# 3917	Right side and left rear of Utility body, back corner of right side of cab, left front fender	None
Dist. 4 83231		1975 Oldsmobile Cutlass	Moderate front end damage	1 Injured	Stopped Occupied	1970 Chevrolet 3-yd. Dump I# 02220 C# 2638 Shadow truck	Minor damage to shoveling apron	1 Injured
Dist. 4 83250	10	1980 Datsun Pickup		None	Stopped Occupied	1972 IHC Dump I# 01820 C# 0329 Shadow truck with attenuator	Right rear of attenuator damaged	None
Dist. 4 83266		1979 Ford	Right front and top	None	Parked	1980 Dodge Pickup I# 00607 C# 4112	Smashed rear section, bed twisted, cab smashed on left side, cab twisted, frane bent, rear springs bent. Total	None
Dist. 4 83273	2	1962 Buick	Minor damage to grill	None	Stopped Occupied	1972 IHC Cargo I# 01064 C# 1501	None	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES – 1/83 – 9/83

PRIVATE VEHICLE						STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 4 83274	15	1981 Toyota	Right front fender, hood, bumper, grill	None	Stopped Occupied	1974 IHC Pickup I# 01000 C# 2950	Rear bumper pushed in	None
Dist. 4 83294	30-50	1982 AMC Eagle	Left front fender, bumper, light, hood, grill	None	Stopped Occupied	1981 IHC Tow Truck I# 02491 C# 2709	Bent stiff leg supports	None
Dist. 4 83305	50	1979 Peterbilt CO	Entire cab	1 Injured	Parked	1980 IHC Cargo I# 01850 C# 1998	Total. Bed, frame, sideboards, drive train, suspension, misc.	None
Dist. 4 83314		Toyota Pickup	Front end	None	Stopped Occupied	1981 IHC Fence Repair I# 03099 C# 1755	Rear tool box supports bent, license plate light broken	None
Dist. 4 83350		1972 Chrysler	Extensive damage to front end	None	Stopped Occupied	1978 Ford Flatbed I# 02497 C# 1231	None	None
Dist. 4 83355		1979 Chevrolet Pickup	Front bumper and grill smashed	None	Stopped Occupied	1980 Dodge Pickup I# 00607 C# 4096	Rear bumper slightly bent	None
Dist. 5 83009		1974 Ford 8000 with Flatbed trailer	Left front bumper, headlight and fender	None	Parked	1981 Dodge Utility Body I# 00830 C# 5379	Right rear bumper and right side of utility bed damaged	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 5 83015		IHC 4-yd. Dump I# 02220 C# 1030	Smashed front end of truck, radiator, fender hood	None	Stopped Occupied	IHC 4-yd. Dump I# 02233 C# 0938	None	None
Dist. 6 83024	45	1977 Datsun 210	Front grill pushed into radiator	1 Injured	Parked	1981 Dodge Utility Body I# 00830 C# 5371	Rear bumper was bent down slightly	None
Dist. 6 83029		1978 Ford T-Bird	Right front fender damaged	None	Mov ing	1971 Dodge 1/2-Ton Pickup I# 00600 C# 0993	Left taillight lens broken and bent bumper	1 Injured
Dist. 6 83033	35-40	1983 Toyota Pickup	Grill knocked off, front bumper bent	None	Backing	1979 GMC Cone truck I# 01037 C# 1583	Dent on left side of rear bumper	None
Dist. 7 83006		AMC Station Wagon	Front end smashed		Mov ing	1980 IHC I# 03017 C# 2163 Shadow truck	Attenuator totaled out	None
Dist. 7 83023		1982 Camero	Right front bumper, hood, fender	None	Parked	1974 Datsun Pickup I# 00400 C# 3163	Tailgate and left rear bumper and taillamp	None
Dist. 7 83057	10-15	1972 VW Bug	Hood	None	Mov ing	1979 Ford Cargo I# 01050 C# 1876	None	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 7 83062	11	1974 Ford Van	Front grill	None	Moving	1975 IHC 4-yd. Dump I# 02423 C# 0959	None	None
Dist. 7 83066	40	1979 Ford Tow Truck		None	Stopped Occupied	I# 02220 C# 2181	Left side tailgage, gas tank, front fender	None
Dist. 7 83071	20-25	1977 Dodge Van	Grill, radiator, power steering and unknown	None	Stopped Occupied	1980 Dodge Pickup I# C# 4358	Front grill and hood had a few dings. Rear bumper is bent and a few scratches on tailgate	None
Dist. 7 83077	30			None	Parked Occupied	1973 GMC Cargo I# 01050 C# 2866		1 Injured
Dist. 7 83101			Front end	None	Stopped Occupied	1972 IHC Dump I# 02420 C# 0135 Shadow truck	Attenuator damage and attenuator mounting bracket	None
Dist. 7 73121	25-30	1981 Dodge Utility 1/2-Ton Cab I# C# 4757	Right front tire and body. Some damage to firewall and dash	1 Injured	Moving	1981 IHC Personnel Hoist I# 03380 C# 1771	Left rear bumper and lights have been destroyed. Kink over left rear tire. Last bin door has to be realigned.	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 7 83133	10-15	Honda Civic	Unknown		Stopped Occupied	1978 FMC Sweeper I# 56708 C# 0568	Left hand pick-up broom arm damaged in two places	None
Dist. 7 83164		Unknown			Parked	1982 Dodge Van I# 01070 C# 2812	Slightly bent rear bumper and left rear fender area	None
Dist. 7 83191	55-60	1982 Toyota Corolla	Left bumper and fender smashed	None	Moving	1974 IHC Utility Body I# 01030 C# 2972	Right rear bumper dented	None
Dist. 7 83216	20	1980 Datsun Pickup	Minor damage to front end	None	Moving	IHC 4-yd. Dump I# 03320 C# 1473	Slight damage to attenuator	None
Dist. 7 83328	25	VW Scirocco	Small dent on hood	None	Stopped Occupied	1980 GMC 2-Ton Spray Rig I# 02250 C# 2025	None	None
Dist. 7 83334		Datsun Pickup			Moving	1971 IHC Cargo I# 02250 C# 8772 Shadow truck	Right side of attenuator slightly damaged	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 7 83342	55-60	1979 GMC 1/2-Ton Pickup	Major front end damage	2 Injured	Moving	1979 IHC Cargo I# 02260 C# 2169 Shadow truck	Lift gate is bent and sprung. Rope reel bracket broken. Crossmember on the end of the frame is bent where hitch is mounted	1 Injured
Dist. 7 83357	2	1971 IHC Cargo E816341	Damaged right head light. Dent in right front fender	None	Stopped Occupied	1971 IHC Cargo I# 02264 C# 8819	Broken reflector in rear	None
Dist. 7 83389		1982 Ford Granada Wagon	Extensive damage to front end	None	Parked Occupied	1972 Ford Cargo I# 01850 C# 0345	Pintle hook and rear step are bent	None
Dist. 7 83460		1982 Yamaha 750	Major damage to front end	1 Fatality	Moving	1971 Ford Dump Loader I# 02417 C# 8675 Shadow truck	Right rear of attenuator damaged	None
Dist. 7 83472	55	1983 Toyota Pickup	Totaled	3 Injured	Parked Occupied	1974 IHC Cargo I# 01050 C# 2971	Frame bent and rear end damaged	2 Injured
Dist. 7 83473	35	1972 Freightliner Semi	Totaled	3 Injured	Stopped Occupied	1974 GMC Van I# 00820 C# 2909	Rear end front of vehicle pushed in	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

	PRIVATE VEHICLE					STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 7 83518	35	1983 Pontiac	Entire front end of vehicle	1 Injured	Stopped Occupied	1980 Dodge Pickup I# 00607 C# 4686	Rear of pickup bed, gas tank, rear bumper and right rear taillight assembly	None
Dist. 7 83533		Kenworth Semi		None	Stopped Occupied	1980 GMC Van I# 00870 C# 4418	Damaged rear and front. Glass.	1 Injured
Dist. 7 83549	5	1968 Ford Fairlane	Right front corner fender small dent	None	Mov ing	1980 Dodge Pickup I# 00807 C# 4982	None	None
Dist. 8 83003				1 Injured	Parked Occupied	1974 Chevrolet Pickup I# 00807 C# 3641	Totaled. Front and rear damaged substantially	1 Injured
Dist. 8 83005	1	1981 Toyota Celica	Dent in trunk deck. Broken taillight lens	None	Parked	1970 IHC Dump I# 13423 C# 8054	None	None
Dist. 8 83009	3	1982 Toyota 4X4 Pickup	Right front fender and door	None	Parked	1974 IHC Dump I# 02423 C# 0642	None	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

PRIVATE VEHICLE						STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 8 83010		1979 GMC Carryall	Right front fender and hood	None	Moving	1972 IHC 4-yd. Dump I# 02421 C# 0168	None	None
Dist. 8 83021		1966 Plymouth	Major damage to right front	1 Injured	Moving	1980 IHC Dump with Loader I# 03017 C# 1799	Hydraulic lines broken at fittings. Attenuator arm bracket bent. Chain bracket broken.	None
Dist. 8 83027		Datsun Pickup		None	Stopped Occupied	1981 IHC 6-Passenger Pickup I# 00804 C# 8958	None	None
Dist. 8 83060		1968 Ford Pickup	Left front portion of vehicle	None	Moving	1981 IHC Cargo I# 01850 C# 1012 Barrier Vehicle	Attenuator damaged and replaced	None
Dist. 8 83069	5	1966 Peterbilt Tractor and Trailer	Bent right front fender and corner of bumper	None	Moving	1972 Ford Cargo I# 01850 C3 0377 Shadow truck	Corner of attenuator dented and taillight broken	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

		PRIVATE VEHICLE				STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 8 83089		1966 White Tractor	Left front corner pushed in	None	Moving	1979 GMC Cone Truck I# 01037 C# 1296	Left rear corner pushed in. Auxiliary motor and conveyor damaged	None
Dist. 9 83005	10-15	IHC 4-yd. Dump I# 02921 C# 2007	Plow frame, front axle, radiator	None	Stopped Occupied	IHC 4-yd. Dump I# 03323 C# 1284	Tailgate sander was destroyed	None
Dist. 9 83013	40	1979 Honda	Right front fender, hood bent	None	Moving	1980 Mack 4-WD Dump I# 13721 CE 1924	None	None
Dist. 9 83019	30	1982 Toyota 4X4 Pickup	Dent in right front hood	None	Moving	1971 Ford Dump I# 02521 C# 0071	Tore sander chute from sander box	None
Dist. 9 83022	50	1973 Dodge Sportsman Motor Home	Right side total	None	Moving	1970 Idaho Norland Rotary Snowplow I# 17010 C# 0485	Broken clearance light, bent left rear engine compartment door.	None
Dist. 9 83031	35	1982 Dodge Aries	Total	1 Fatality	Parked Occupied	1981 White I# 03358 C# 2664 Shadow truck	Damage to the two tool boxes on rear, pintle hook, glad hands for air supply	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

PRIVATE VEHICLE						STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 9 83039	15-20	1982 GMC Utility	Front bumper	None	Stopped Occupied	IHC Dump I# 03323 C# 1284	Left rear rim bent	None
Dist. 10 83004		1973 GMC Pickup	Slight damage to right rear fender	None	Stopped Occupied	IHC Pickup with Camper I# 01000 C# 1536	Slight damage to camper. Fiberglass fender torn from body	None
Dist. 10 83009		1978 Peterbilt 3-Axle Truck	Right side of truck cab	None	Stopped Occupied	1972 Ford 2-yd. Dump I# 01820 C# 0304	Left side of truck bed, left mirror, left muffler and taillight, rear axle knocked loose	None
Dist. 10 83035	20-25	1968 Pontiac Bonneville	Right rear fender chrome strip down side. Front fender and bumper	None	Moving	1979 Mack 4-WD Dump I# 12721 C# 1438	None	None
Dist. 10 83039	3-4	1980 Mercury Monarch		None	Stopped Occupied	Case Loader with Blower I# 41864 C# 0893	None	None

TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

PRIVATE VEHICLE						STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 10 83057	35	1978 Chevrolet Blazer	Right front fender, hood, grill	None	Moving	1972 Snowblast Rotary Snowplow I# 17007 C# 0116	Bent chain hangers	None
Dist. 10 83102		1962 Mercury Monterey	Right rear bumper	None	Parked	1970 Dodge I# 02402 C# 8119 Barrier Vehicle	Left rear corner of attenuator. Left front corner	None
Dist. 11 83007	0-1	1979 Honda Accord	Right headlights Fender maybe bumper	None	Stopped Occupied	1983 Dodge Van	None	None
Dist. 11 83026	25	Dodge Colt	Front bumper, grill and fender bent	None	Moving	1975 Dodge Pickup I# 00801 C# 3455	Rear bumper bent in at center	None
Dist. 11 83055	65	1980 Mercedes 240D	Extensive front end damage	2 Injured	Parked	1972 Dodge Pickup I# 00600 C# 1967	Rear, frame, bed and cab damaged	None
Dist. 11 83079		Datsun Pickup	None	None	Moving	1975 IHC 4-yd. Dump I# 02420 C# 0831 Attenuator	None	None

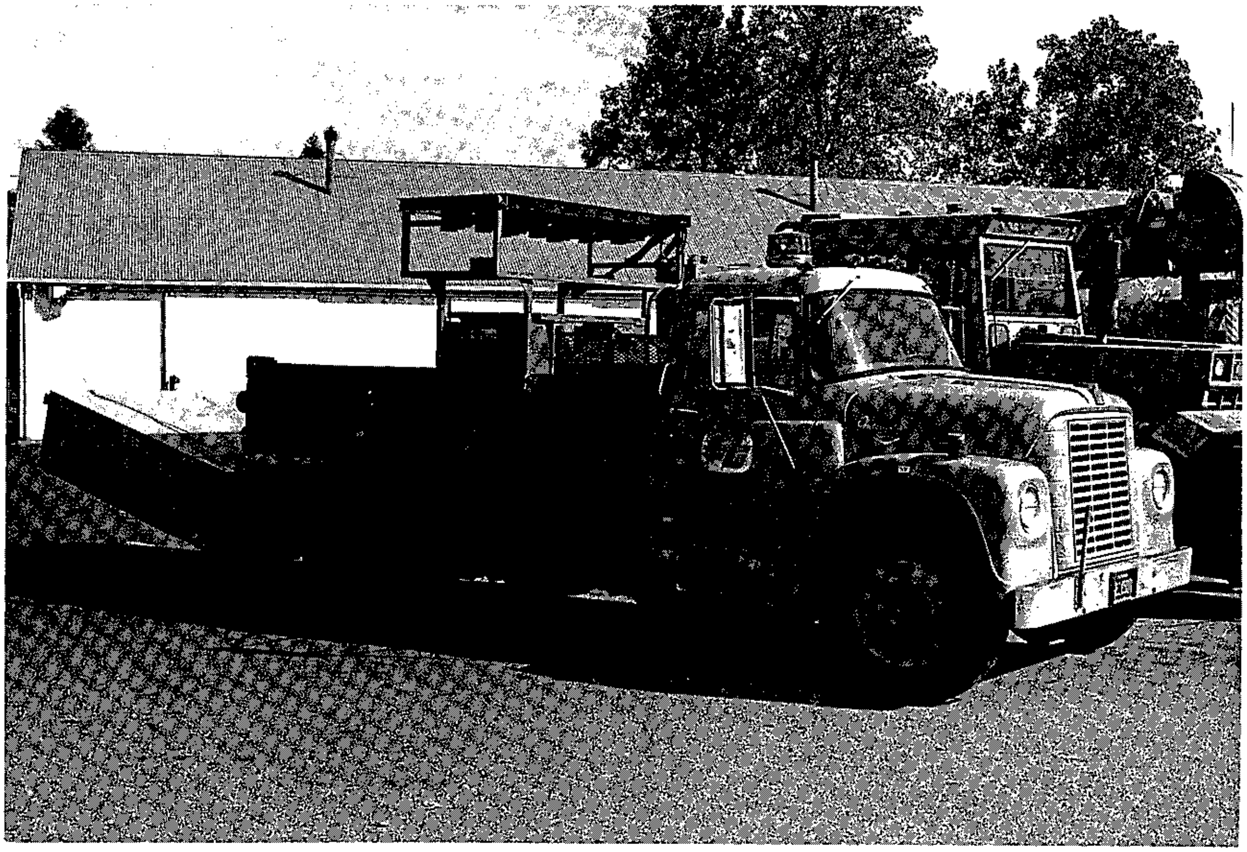
TABLE D.2 SUMMARY OF REAR END IMPACTS INTO CALTRANS SHADOW VEHICLES - 1/83 - 9/83

PRIVATE VEHICLE						STATE VEHICLE		
No.	Est. Speed	Type	Damage	Injuries[1]	Location[2]	Type	Damage	Injuries[1]
Dist. 11 83110		1979 VW Rabbit	Extensive front end damage	2 Injured	Moving	1973 IHC Cargo I# 01050 C# 2353	Extensive front end damage, left rear frame bent, rotating light cover broken, right mirror destroyed	1 Injured

APPENDIX E

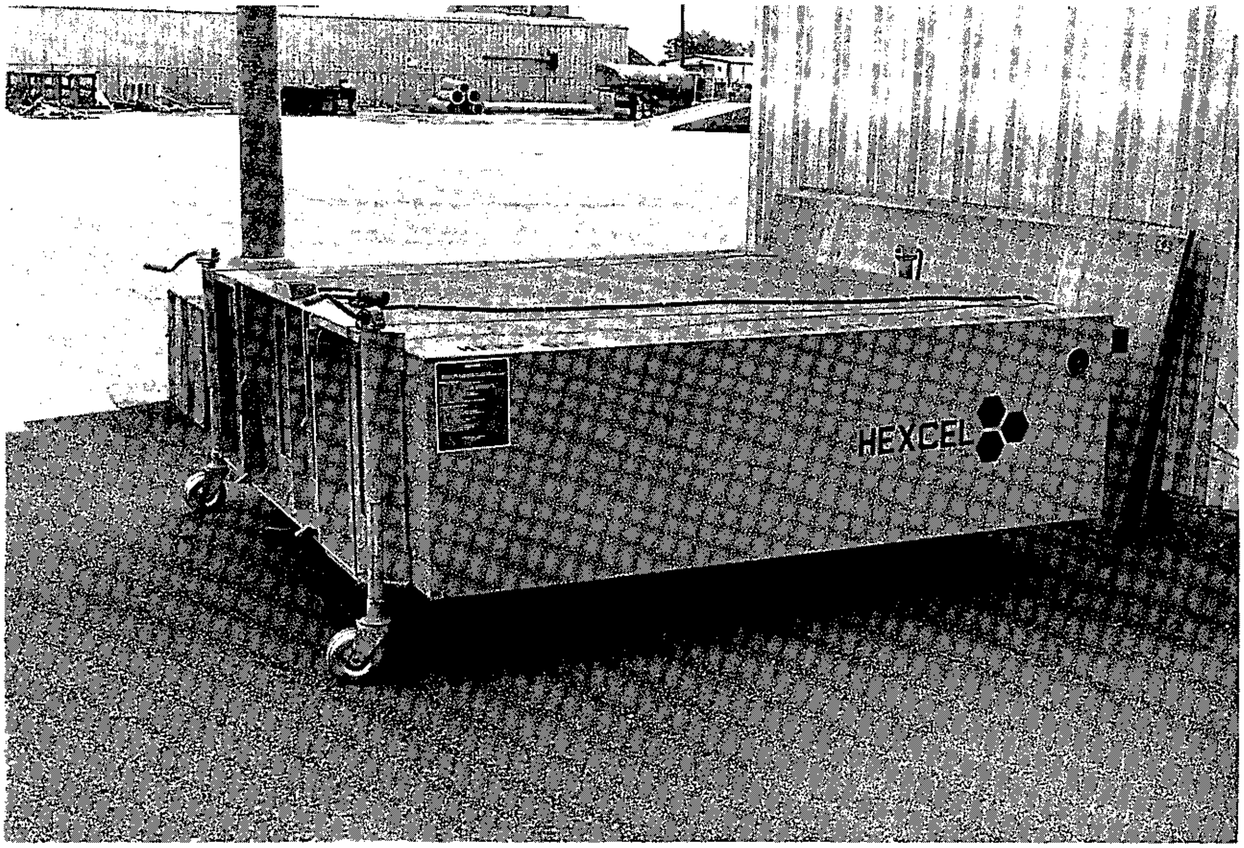
Photos of Lightweight TMA's and PMA's in service.

FIGURE E-1



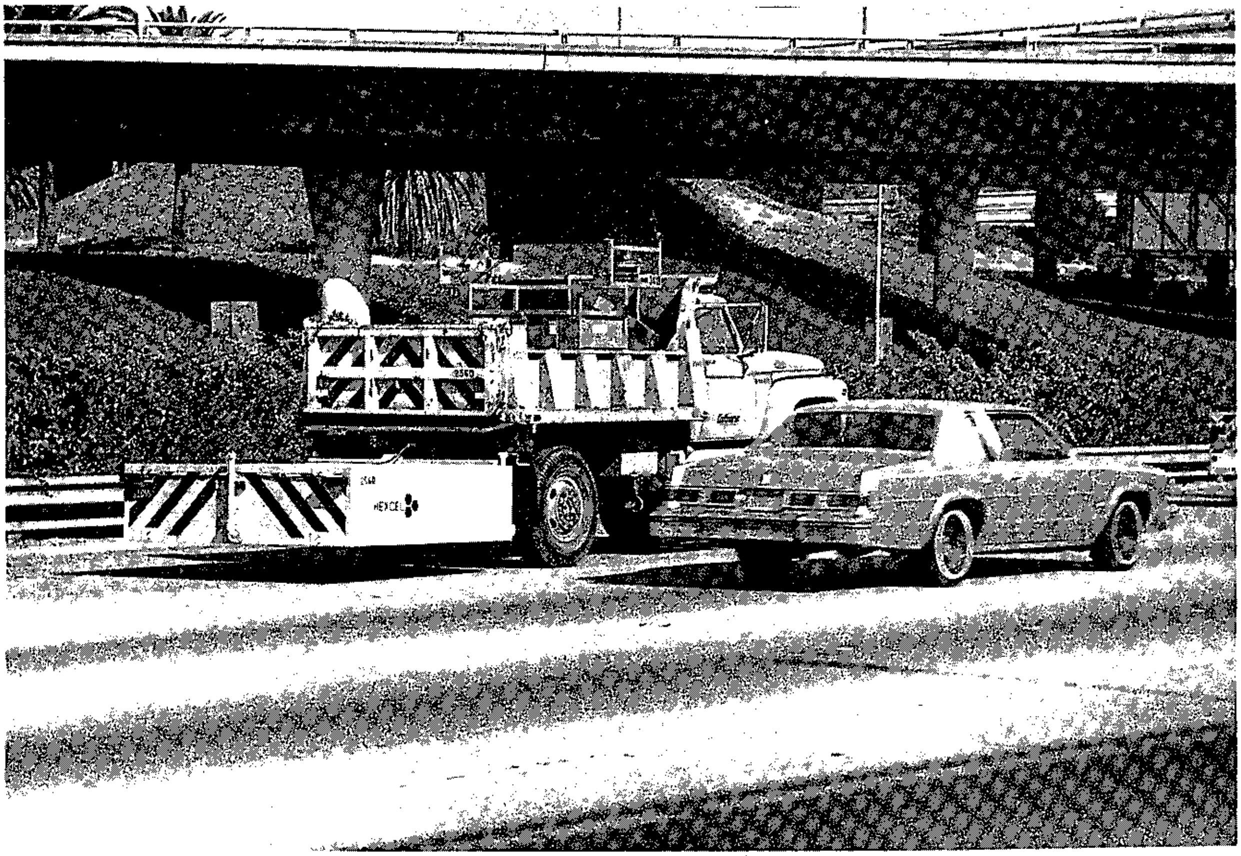
Typical Barrier Truck with TMA (Raised Position)
and Self Powered Skid Mount Sequential Arrowboard.

FIGURE E-2



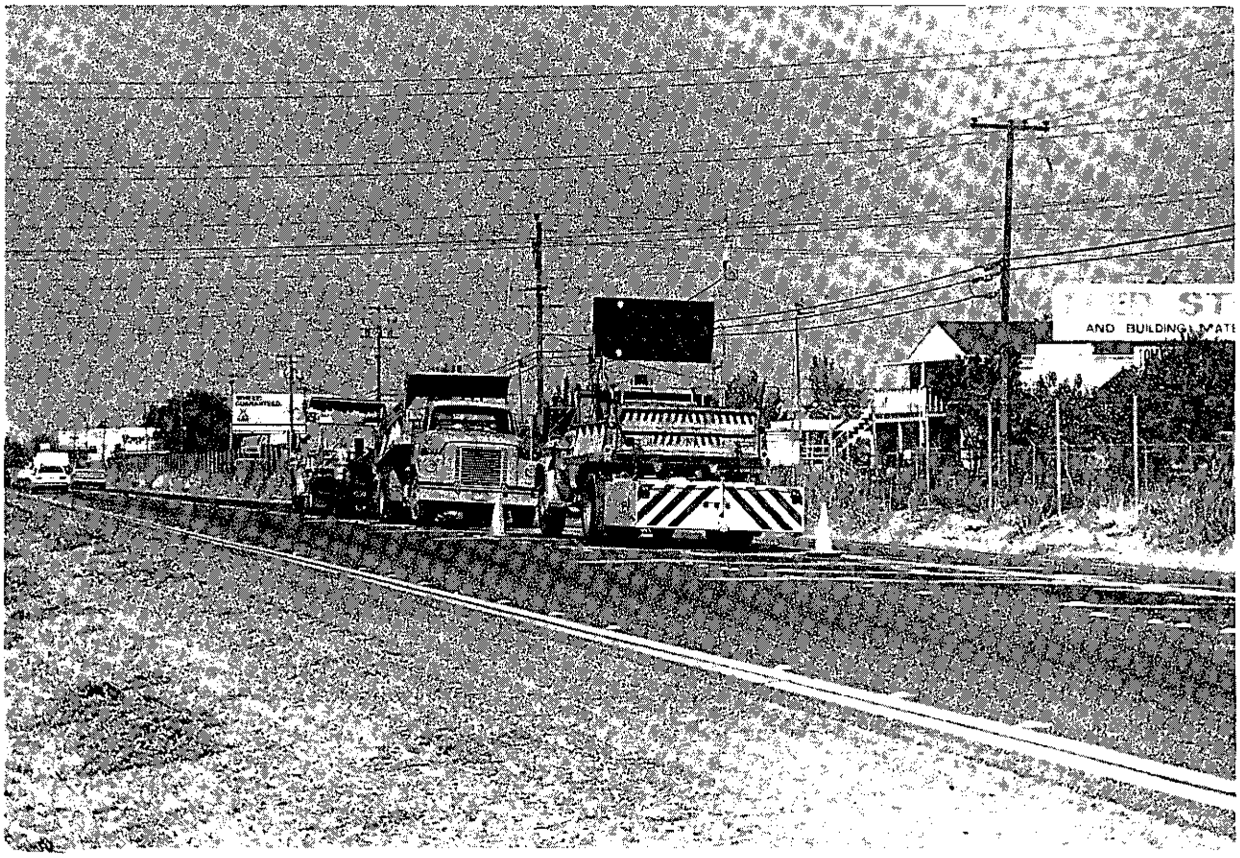
Lightweight TMA Removed from Truck

FIGURE E-3



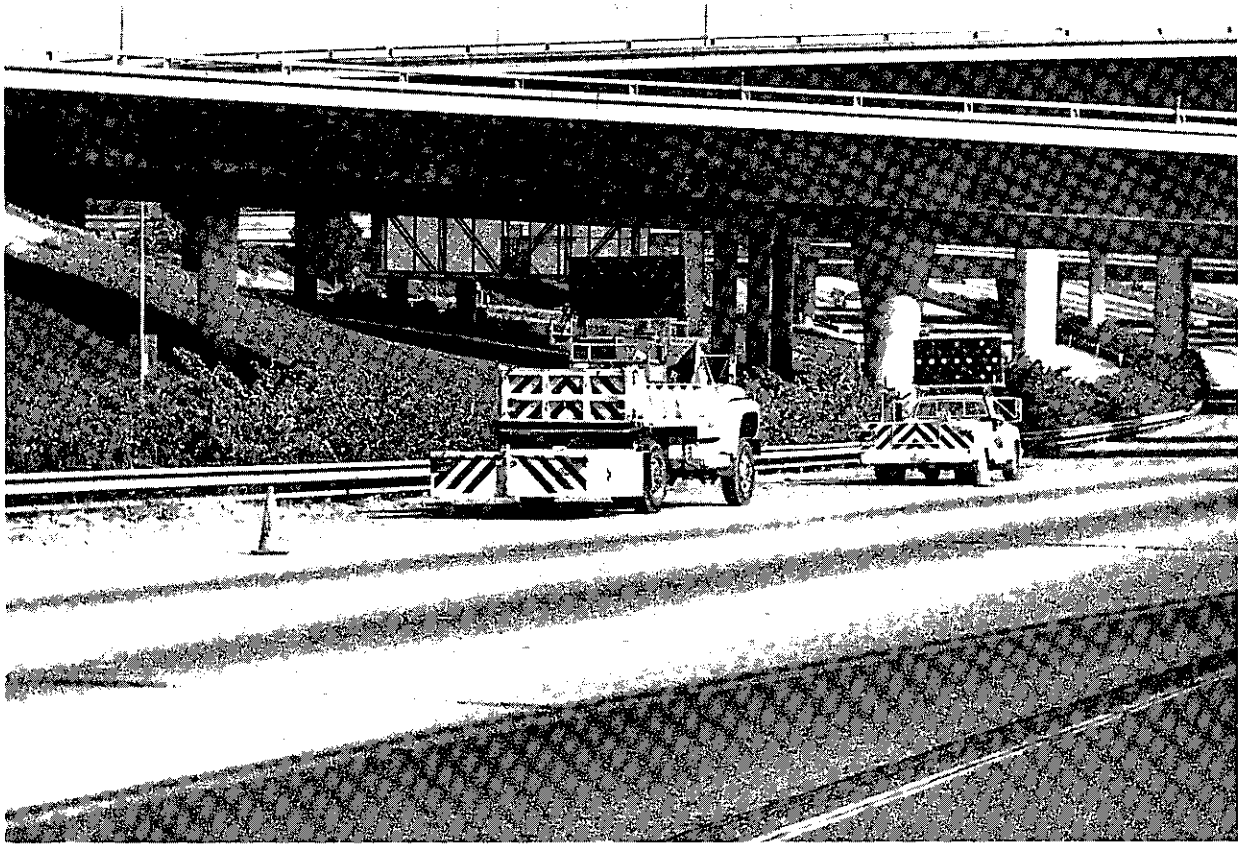
TMA in Use

FIGURE E-4



Barrier Truck with TMA in Lane Closure

FIGURE E-5

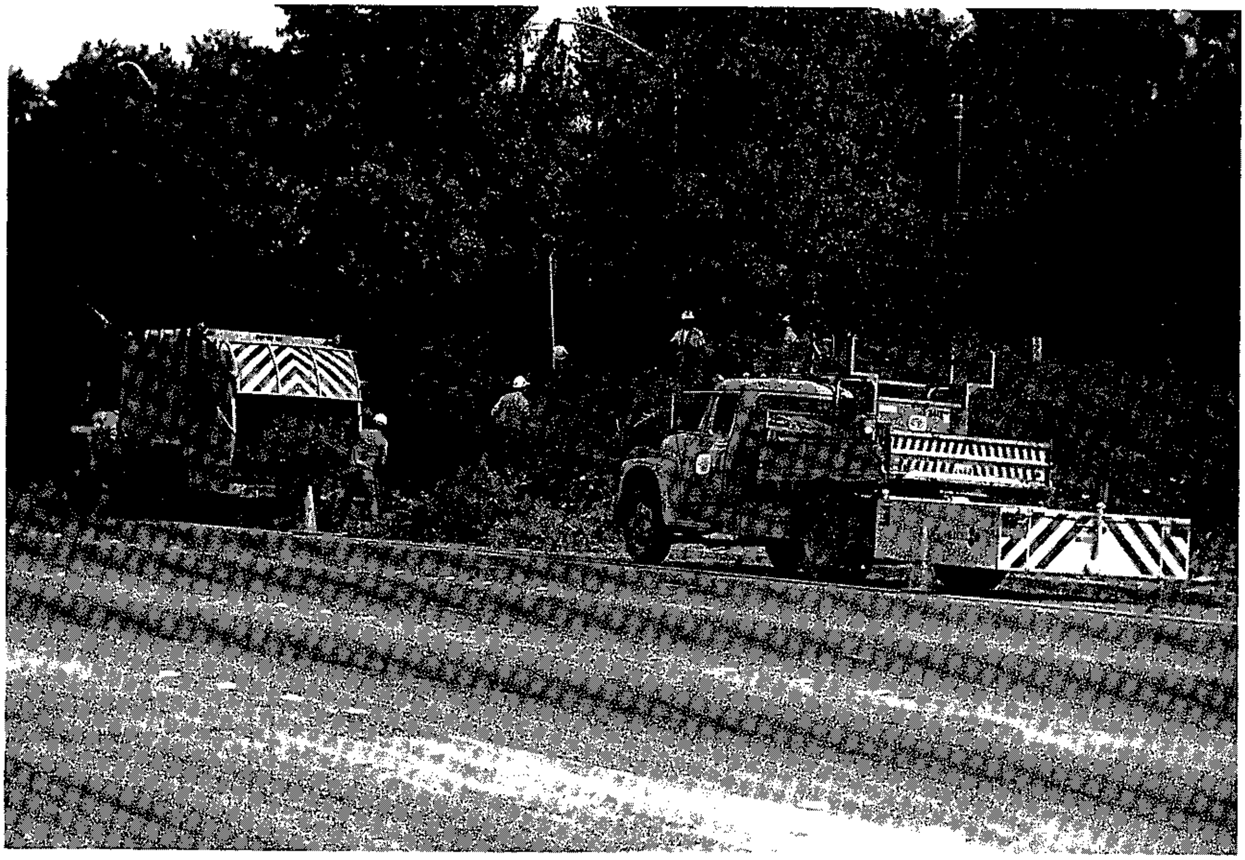


Barrier Truck Shadowing Cone Truck,
Setting Cones for Lane Closure

FIGURE E-6

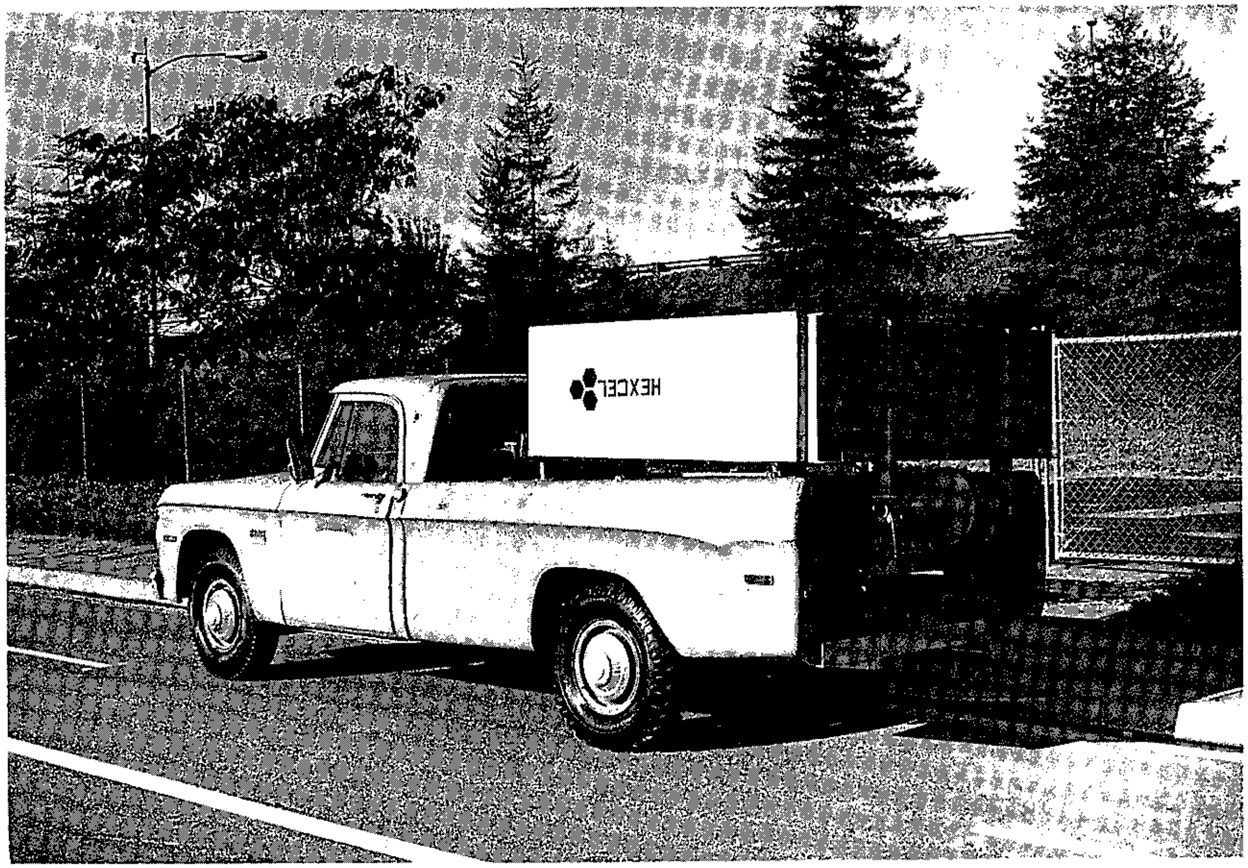
Barrier Truck Shadowing Cone
Truck Picking Up Cones

FIGURE E-7



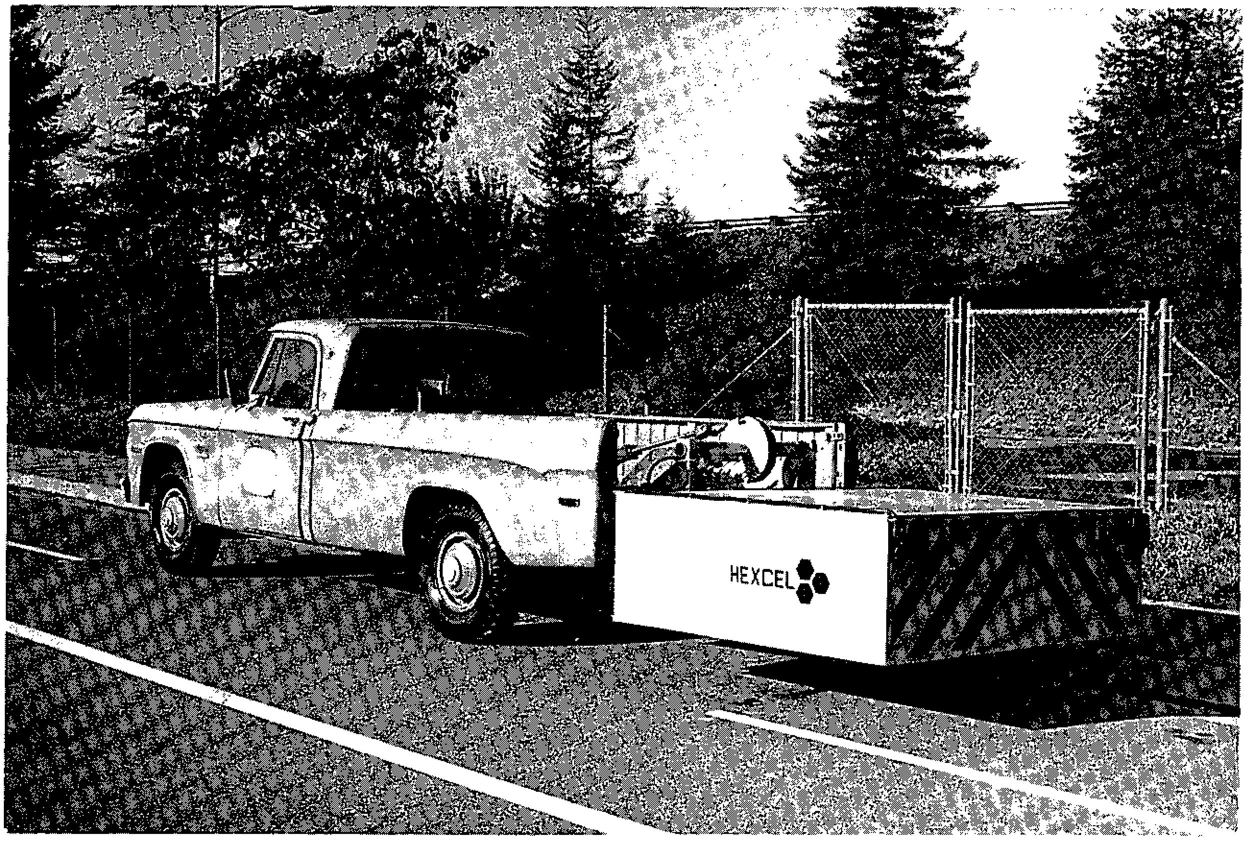
Barrier Truck Parked in Shoulder
Closure Protecting Workers

FIGURE E-8



Pickup Mounted Attenuator
in Stored Position

FIGURE E-9



Pickup Mounted Attenuator
in Operating Position